

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Binqiang Shi

Patent Application No.: 09/851,839

Filed: May 9, 2001

For: "NOVEL EPITAXY WITH COMPLIANT
LAYERS OF GROUP-V SERIES"

) On Appeal to the

) Board of Appeals

) Group Art Unit: 1765

) Examiner: Nadine G. Norton

) Date: December 22, 2003

BRIEF ON APPEAL

Mail Stop Appeal Brief - Patents

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Sir:

This is an appeal from the Final rejection, dated October 9, 2003, for the above identified patent application. The Applicant submits that this Appeal Brief is being timely filed, since the notice of Appeal was filed on October 20, 2003.

REAL PARTY IN INTEREST

The present application has been assigned to HRL Laboratories, LLC of Malibu, CA.

STATUS OF CLAIMS

01/02/2004 MDANTE1 00000080 09851839

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Claims 1 - 27, 29-33 and 39-40 are the subject of this Appeal and are reproduced in the accompanying appendix. The Examiner has withdrawn Claims 34 - 38 from consideration. Claim 28 has been canceled.

STATUS OF AMENDMENTS

No Amendment After Final Rejection has been entered.

SUMMARY OF INVENTION

The invention described and claimed in the present application relates to the process or method of growing of a group III-V crystal on top of another group III-V crystal (substrate), without introducing lattice-mismatch defects.

The method comprising the steps of: thermal desorption cleansing of the substrate; in situ introduction of condensed group-V species; deposit of a mono-layer of group-III atoms on the group-V layer; and epitaxial growth of crystal over the mono-layer (see in particular claims 1, 27 and 32).

As a consequence, strain relaxation associated with lattice-mismatched epitaxy is suppressed there by preventing formation of dislocation defects (see specification, page 3 lines 9-17).

A preferred embodiment of the method of growing of a group III-V crystal on top of another group III-V crystal (substrate) is depicted in Figures 3-6.

Figure 3 shows a step of thermal desorption cleansing of the substrate. More specifically, substrate 7 is first heated inside a growth chamber 6, to temperature T_s , where T_s ranges from about 495°C to about 600°C. Vapor 8 comprising group-V species is introduced in the growth

chamber 6, through gate 19, when substrate 7 is heated. The pressure P of the vapor 8 may range from about 0.004 pa to about 0.012 pa, pressure P is larger than the vapor pressure P_s of the substrate 7 at temperature T_s . The temperature of the vapor 8 may range from about 300°C to about 1000°C. The substrate 7 is then annealed under this over-pressure of group-V species vapor, at temperature T_s , and desorption of surface oxides 9 from the substrate 7 takes place, with the surface oxides being removed from chamber by pump 20. See page 6 of the specification.

Figure 4 shows a step of in situ introduction of condensed group-V species. More specifically, in this step a vapor 13 comprising a group-V species is introduced onto surface of the substrate by opening shutter 19. When the temperature T_s of the substrate 7 is appropriately low, between about 30°C and about 250°C, and the pressure P_c of the group-V vapor 13 is adequate, about 0.004 pa to about 0.012 pa, condensation of the group-V species on the substrate 7 takes place. The thickness of the layer 11 of group-V species can be controlled by varying the temperature T_s of the substrate 7. The amount of desorption from the condensed layer of group-V species is dependent on the temperature. In other words, different thicknesses of the layer 11 can be achieved by varying the temperature T_s . The temperature T_s of the substrate 7 is preferably set such that the thickness of the layer of the group-V species falls into a range of several Å to a few tens of Å. See pages 6-7 of the specification.

Figure 5 shows a step of depositing a mono-layer of group-III atoms on the group-V layer. More specifically, in this step a vapor of group-III atoms 17 is introduced in the growth chamber 6, wherein the vapor 17 condenses on the surface of the substrate 7 above the layer of group-V atoms 11, forming a mono-layer of group-III atoms 12. The vapor 17 is introduced at temperatures ranging from about 780°C to about 1250°C and at a pressure of about 5×10^{-5} pa. The layer 12 may have a thickness ranging from one atom to a few atoms. As vapor 17

condenses over layer 11, the substrate 7 is kept at a temperature T_d ranging from about 30°C to about 250°C and the pressure of the group-V vapor 13 is maintained around 0.008 pa. The layer 12 is then annealed by raising the temperature of the substrate T_d to a temperature from about 400°C to about 580°C, under a pressure of group-V vapor 13 of about 0.008 pa. Such mono-layer of group-III atoms 12 has the property of changing the desorption tendency of the group-V species layer 11 lying underneath, and allows retention of the group-V species layer 11 during the annealing phase, which precedes the actual epitaxial growth of the crystal at an optimal growth temperature. The group-III atoms in the mono-layer 12 will seek lattice sites of a lower free energy during annealing, and will therefore form a propitious starting atomic plane for subsequent epitaxial growth. Because the bonding between group-V molecules in layer 11 is much weaker than that between atoms of the solid crystal to be grown, the group-V molecules will relocate during the subsequent epitaxy to accommodate the lattice mismatch between the solid substrate crystal 7 and the desired solid crystal to be grown over layer 12. See pages 7-9 of the specification.

Figure 6 shows a step of epitaxial growth of crystal over the mono-layer. More specifically, in this step growth of bulk group III-V species layer 18 is initiated by reopening the shutter 14 of the group-III furnace 15. In the preferred embodiment, group-V species and group-III species are introduced in the growth chamber with the ration of the group-V flux to the group-III flux being maintained in the range of about 1.5 to about 3. See page 9 of the specification.

Overview of independent Claims 1, 27 and 32

This embodiment of the method of growing of a group III-V crystal on top of another group III-V crystal (substrate), without introducing lattice-mismatch defects is exemplified in independent Claims 1, 27 and 32.

Independent Claim 1 claims a method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the step of: cleansing a surface of the first crystal by thermal desorption (as described with reference to Figure 3); depositing a first layer of a first material over the surface of the first crystal (as described with reference to Figure 4); depositing a second layer of a second material over the first layer (as described with reference to Figure 5); and epitaxially growing the second crystal over the second layer (as described with reference to Figure 6); wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects.

Independent Claim 27 claims a method of preparing a substrate for subsequent epitaxial growth of a crystal over the substrate, the method comprising the steps of: cleansing a surface of the substrate by thermal desorption (as described with reference to Figure 3); depositing a first layer of a first material over the surface of the substrate (as described with reference to Figure 4); and depositing a second layer of the second material over the first layer (as described with reference to Figure 5), wherein the crystal is deposited over the second layer (as described with reference to Figure 6), wherein the first layer accommodates strain accumulated between the substrate and the crystal during epitaxial growth, thereby preventing strain relaxation and formation of dislocation defects.

Finally, independent Claim 32 claims a method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of: a) extracting surface oxides from a surface of the substrate by thermal desorption (as described with reference to Figure 3), the thermal desorption including the steps of: heating the substrate to a temperature of about 600°C (as described on page 10 of the specification); and annealing the

substrate for about 10 minutes under a pressure of As₂ vapor of about 0.008 pa (as described on page 10 of the specification); b) depositing a condensed layer of As₂ on the surface of the substrate (as described with reference to Figure 4), depositing a condensed layer including the steps of: lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As₂ vapor pressure of about 0.008 pa, whereby a condensed layer of As₂ is formed on the surface of the substrate (as described on page 10 of the specification); and adjusting the thickness of the condensed layer As₂ by raising the temperature of the substrate to about 250°C, thereby thinning the condensed layer of As₂ to several tens of Å (as described on page 10 of the specification); and c) depositing a mono-layer of In atoms over the condensed layer As₂ (as described with reference to Figure 5), the depositing a mono-layer comprising the steps of: introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As₂ vapor pressure of about 0.008 pa (as described on pages 10-11 of the specification); and raising the temperature of the substrate to about 400°C while the As₂ vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer (as described on pages 10-11 of the specification); wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer.

Overview of dependent claims 2-26, 29-31, 33, 39 and 40

Claim 2 depends on Claim 1. Dependent Claim 2 recites that the step of cleansing the surface of the first crystal by thermal desorption of Claim 1 includes the steps of bringing a temperature of the first crystal to T_s°C, T_s ranging from about 495°C to about 600°C (see page 6, lines 9-10 of the specification); introducing a desorption vapor having a desorption vapor pressure (see page 6, lines 10-14 of the specification); and annealing the first crystal under the desorption vapor

pressure at temperature T_s (see page 6, lines 15-18 of the specification); wherein the desorption vapor pressure is greater than a vapor pressure of the first crystal at temperature T_s (see page 6, lines 10-15 of the specification).

Claim 3 depends from Claim 2. Dependent Claim 3 recites that the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa and wherein surface oxides of the first crystal are desorbed (see page 6, lines 10-18 of the specification).

Claim 4 depends from Claim 3. Dependent Claim 4 recites that the first crystal comprises group-III/Group-V species, and the desorption vapor comprises group-V species (see page 6, lines 5-7 and 15-18 of the specification).

Claim 5 depends from Claim 4. Dependent Claim 5 recites that the first crystal comprises GaAs, GaP, InAs or InP, and wherein the desorption vapor comprises As_2 or As_4 if the first crystal is GaAs or InAs, or the desorption vapor comprises InAs, P_2 or P_4 if the first crystal is GaP or InP (see page 6, lines 5-7 and 10-11 of the specification).

Claim 6 depends from Claim 2. Dependent Claim 6 recites that the step of depositing a first layer of Claim 2 includes the steps of: introducing a first vapor of the first material, wherein part of the first vapor condenses on the surface of the first crystal, thereby forming the first layer; and adjusting a thickness of the first layer by varying a temperature of the first crystal (see page 7, lines 4-16 of the specification).

Claim 7 depends from Claim 6. Dependent Claim 7 recites that the first vapor is introduced at a temperature which is less than an optimal growth temperature for epitaxy (see page 7, lines 1-4 of the specification).

Claim 8 depends from Claim 7. Dependent Claim 8 recites that the first crystal comprises group-III/group-V species, and the first material comprises group-V species (see page 6, lines 5-7 and page 7, lines 1-4 of the specification).

Claim 9 depends from Claim 8. Dependent Claim 9 recites that the first crystal comprises GaAs, GaP, InAs or InP, and the first material comprises As₂, As₄, P₂ or P₄ (see page 6, lines 5-7 and page 7, lines 1-4 of the specification).

Claim 10 depends from Claim 9. Dependent Claim 10 recites that the thickness of the first layer ranges from approximately a few Å to approximately a few tens of Å (see page 7, lines 13-15 of the specification).

Claim 11 depends from Claim 10. Dependent Claim 11 recites that the step of introducing a first material includes the step of opening a first shutter blocking a growth chamber from a first vapor source (see page 7, lines 4-6 of the specification).

Claim 12 depends from Claim 6. Dependent Claim 12 recites that the step of depositing a second layer of a second material of Claim 6 includes the steps of: introducing the second vapor, a temperature of the first crystal being maintained at T_d within a range of about 30°C to about 250°C, wherein at least part of the second vapor condenses over the first layer; annealing the second layer by raising the temperature of the first crystal from T_d to a temperature of about 400°C to about 580°C, under a pressure of the first vapor of about 0.008 pa (see page 8, lines 14-18 of the specification).

Claim 13 depends from Claim 12. Dependent Claim 13 recites that an amount of the second vapor introduced is such that the second layer is formed by a mono-layer of atoms of the second material (see page 7, lines 19-20 and page 8, lines 1-5 of the specification).

Claim 14 depends from Claim 13. Dependent Claim 14 recites that the step of introducing the second vapor of Claim 13 comprises the steps of: providing a furnace containing a second vapor of the second material; opening a second shutter allowing the second vapor to travel from the furnace to a growth chamber; wherein the second shutter is opened for a predetermined time duration, whereby to allow a predetermined amount of the second vapor to travel from the furnace to the growth chamber, the predetermined amount of the second vapor being determined by the number of atoms of the second material necessary to form a mono-layer of said atoms over the first layer (see page 8, lines 2-10 of the specification).

Claim 15 depends from Claim 14. Dependent Claim 15 recites that the first crystal comprises group-III/group-V species, the first material comprises group-V species, and the second material comprises group-III species (see page 6, lines 5-7 and page 7, lines 19-20 of the specification).

Claim 16 depends from Claim 15. Dependent Claim 16 recites that the first crystal is selected from the group consisting of GaAs, GaP, InAs and InP, the first material is selected from the group consisting of As₂, As₄, P₂ and P₄, the second material is selected from the group consisting of In, Ga and Al or any combination thereof, and wherein the second vapor has a pressure of about 5×10^{-5} pa, the second vapor has a temperature of about 780°C if the second material is In, the second vapor has a temperature of about 900°C if the second material is Ga, the second vapor has a temperature of about 1200°C if the second material is Al (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 1-10 of the specification).

Claim 17 depends from Claim 16. Dependent Claim 17 recites that for the second material, combinations of Ga, Al, and In, are in a relative ratio substantially equal to the ratio of elements forming the second crystal which is to be epitaxially grown (see page 8, lines 1-5 of the specification).

Claim 18 depends from Claim 16. Dependent Claim 18 recites that the second shutter is opened for a time duration ranging from about 1 second to about 3 seconds (see page 8, lines 1-5 of the specification).

Claim 19 depends from Claim 18. Dependent Claim 19 recites that a number per surface area of group-III atoms forming the mono-layer is about $6.5 \times 10^{14} \text{ cm}^{-2}$ and wherein the second shutter is opened for 2.2 seconds (see page 10, lines 18-20 of the specification).

Claim 20 depends from Claim 16. Dependent Claim 20 recites that the thickness of the first layer ranges from a few Å to a few tens of Å (see page 7, lines 13-14 of the specification).

Claim 21 depends from Claim 12. Dependent Claim 21 recites that the second crystal is a group-III/group-V crystal and wherein the step of epitaxially growing the second crystal of Claim 12 includes the steps of: introducing group-III species into a growth chamber; introducing group-V species into the growth chamber; maintaining a temperature inside the growth chamber near an optimal temperature for epitaxial growth of the second crystal (see page 9, lines 10-15 of the specification).

Claim 22 depends from Claim 21. Dependent Claim 22 recites that the group-V species is introduced by opening a first shutter whereby to let a group-V flux into the growth chamber, and the group-III species is introduced by opening a second shutter whereby to let a group-III flux into the growth chamber (see page 9, lines 10-15 of the specification).

Claim 23 depends from Claim 22. Dependent Claim 23 recites that the ratio of the group-V flux to the group-III flux is substantially in the range of about 1.5 to about 3 (see page 9, lines 10-15 of the specification).

Claim 24 depends from Claim 23. Dependent Claim 24 recites that the second crystal is selected from the group consisting of InAs, $\text{In}_x\text{Ga}_{1-x}\text{As}$, $\text{In}_x\text{Al}_{1-x}\text{As}$ or GaP (see page 9, lines 10-15 of the specification).

Claim 25 depends from Claim 1. Dependent Claim 25 recites that the method is used to manufacture semiconductor devices (see page 12, lines 4-10 of the specification).

Claim 26 depends from Claim 25. Dependent Claim 26 recites that the method is used in microelectronic and optoelectronic applications (see page 1, line 9 of the specification).

Claim 29 depends from Claim 27. Dependent Claim 29 recites that the substrate comprises group-III/group-V species; the crystal comprises group-III/group-V species; the first material comprises group-V species; and the second material comprises group-III species (see page 6, lines 5-7; page 7, lines 1-5; page 7, lines 19-20; and page 8, lines 1-5 of the specification).

Claim 30 depends from Claim 29. Dependent Claim 30 recites that the first layer has a thickness within a range of approximately a few Å to a few tens of Å (see page 7, lines 13-14 of the specification).

Claim 31 depends from Claim 30. Dependent Claim 31 recites that the second layer is a monolayer of group-III atoms (see page 7, lines 19-20 of the specification).

Claim 33 depends from Claim 32. Dependent Claim 33 recites the step d) of epitaxially growing the InAs layer, the step d) including the steps of: introducing a flux of In vapor; introducing a flux As vapor; and maintaining the temperature of the substrate between about 400°C and about 450°C; wherein the ratio of the flux of As vapor to the flux of In vapor is maintained at about 2.5 (see page 11, lines 9-12 of the specification).

Claim 39 depends from Claim 1. Dependent Claim 39 recites that the first crystal comprises the first material of the first layer and the second crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 2-3; and page 9, lines 10-15 of the specification).

Claim 40 depends from Claim 27. Dependent Claim 40 recites that the first crystal comprises the first material of the first layer and the crystal comprises the second material of the second layer; and wherein the first material is a group-V species and the second material is a group-III species (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 2-3; and page 9, lines 10-15 of the specification).

Claims 2, 3, 4 and 5 as originally filed include the phrase "desorption vapor." These claims were never amended. Due to editorial oversight the word "desorption" was omitted from the phrase "desorption vapor" in our responses to the Examiner's Office Actions. The Applicant respectfully submits that the word "desorption" is included in Claims 2, 3, 4 and 5 since the Examiner's rejections of these claims are based on language as originally filed with the word "desorption."

ISSUES

Issue 1: Whether Claims 1 - 11, 25 - 27, 29 - 31, and 39 - 40 are patentable under 35 U.S.C. 103(a) over Pessa et al., U.S. Patent No. 4,876,218 (hereinafter “Pessa”) in view of Hayakawa et al. U.S. Patent No. 4,824,518 (hereinafter “Hayakawa”)?

Issue 2: Whether Claims 12 - 16 and 18 - 22 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and further in view of Ogasawara U.S. Patent No. 4,897,367 (hereinafter “Ogasawara”)?

Issue 3: Whether Claims 17 and 23 - 24 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and further in view of Grunhaner et al., U.S. Patent No. 5,094,974 (hereinafter “Grunhaner”)?

Issue 4: Whether Claims 32 - 33 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and Grunhaner and further in view of Kubiak et al., U.S. Patent No. 4,330,360 (hereinafter “Kubiak”)?

GROUPING OF CLAIMS

For each ground of rejection which the Applicant contests herein and which applies to more than one claim, such additional claims, to the extent separately identified and argued below, do not stand or fall together.

THE ARGUMENT

Issue 1: Whether Claims 1 - 11, 25 - 27, 29 - 31, and 39 - 40 are patentable under 35 U.S.C. 103(a) over Pessa et al., U.S. Patent No. 4,876,218 (hereinafter “Pessa”) in view of Hayakawa et al. U.S. Patent No. 4,824,518 (hereinafter “Hayakawa”)?

In section 2 of the Office Action of June 23, 2003, the Examiner rejects Claims 1-11, 25-27, 29-31 and 39-40 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa. The Applicant respectfully disagrees with the conclusions that the Examiner has made with regard to the teaching of the cited prior art and submits that Pessa and Hayakawa do not teach, disclose or suggest all of the claim limitations of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on Pessa and Hayakawa, and the rejection of Claims 1-11, 25-27, 29-31 and 39-40 based on Pessa and Hayakawa should be overturned on appeal.

Now the rejection of the specific claims by the Examiner based on the disclosure of Pessa and Hayakawa will be addressed.

Claims 1

Regarding Claim 1, the Examiner asserts, in part, that Pessa: discloses a method of a GaAs film on the surface of a Si or GaAs substrate, where an effusion cell 3 contains a Ga elementary component of a GaAs compound, e.g. Ga atoms, and an effusion cell 4 contains the As elementary component, e.g. as As₄ molecules; teaches heating the substrate to a first growing temperature of 100°C to 500°C, heating the Ga effusion cell

3 to 800°C and heating the As effusion cell 4 to 300°C; teaches opening a shutter 6 in front of the As cell and a vapor beam of As₄ molecules is allowed to act on the surface of the substrate for a period of time which is required for the formation of one atom layer and excess arsenic is removed through re-evaporation and the growing surface by one atom layer only. The Examiner asserts that this reads on the Applicant's first layer of material over the substrate.

The Examiner further asserts, in part, that Pessa: teaches a shutter 6 is closed and a shutter 5 is opened and a vapor beam containing Ga atoms is allowed to act on the growing surface until a number of Ga atoms corresponding to a single atom layer reaches the growing surface. The Examiner asserts that this reads on the Applicant's second layer of second material over the first layer.

The Examiner continues, that the multiple As layers and Ga layers of atoms form a buffer layer (having a thickness of 40 Å to 3000 Å), where the buffer layer causes reduction in lattice strain by creating mismatch dislocations which have a relatively low range of action and which as a result lead to the reduction of threading dislocations. The Examiner asserts that this reads on the Applicant's recite first layer which "substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects" recited by Claim 1.

The Examiner also asserts that Pessa: teaches after the growth of the buffer layer, the substrate is heated to a second growth temperature ranging from 500-700°C and both the Ga and As beams act simultaneously on the growing surface until the desired GaAs film

thickness is obtained by Molecular Beam Epitaxy. The Examiner asserts that this reads on the Applicant's second crystal.

The Applicant respectfully submits that the Examiner failed to fully consider the complete teachings of Pessa. Applicant's invention would not have been obvious to a person having ordinary skill in the art based on the complete teachings of Pessa.

Although the Examiner asserts that Pessa's layers are one atom thick, the Examiner fails to acknowledge that the process of stacking the Ga layer over the As layer continues until the desired GaAs buffer layer thickness is obtained, see column 3, lines 60-64 of Pessa. Pessa teaches that the thickness of the buffer layer may vary within a range from 4 to 300 nm, preferably from 50 to 150 nm, see column 4, lines 5-9. That translates to a minimum and maximum thickness of 40 Å to 3000 Å. Based on these numbers it would require many individual As and Ga one atom layers to create the desired buffer layer.

Additionally, according to Pessa, the buffer layer, grown by Migration Enhanced Epitaxy (MEE), seems to cause reduction in lattice strain by creating mismatch dislocations (type I) which have a relatively low range of action and which as a result lead to the reduction of disadvantageous threading dislocations penetrating deep into the GaAs layer, see column 2, lines 35-40 of Pessa. Type I dislocations are pure edge dislocations, that is the dislocation line runs along the interface and it is only the interfacial region that is degraded, see column 1, lines 39-49 of Pessa. Since interface region gets degraded, it would make sense to make that region as thick as

possible, that is to have a thick buffer layer. Of course, that is exactly what Pessa teaches.

Based on the Pessa, the Examiner expects a person, having ordinary skill in the art, to use only two one atom thick layers of Ga and As (i.e. to use only two layers out of many layers comprising Pessa's thick buffer) when Pessa specifically teaches of pure edge dislocations and a thick buffer layer to accommodate these dislocations. Of course, the Examiner makes this assertion in order to try to make a case that Pessa meets the language of Claim 1 which recites that the second crystal is epitaxially grown over the second layer. However, it is not clear what would prompt a person, having ordinary skill in the art, to use only a two atom thick buffer layer (one layer of Ga atoms and one layer of As atoms) knowing that MEE creates mismatch dislocations that would significantly degrade such a two atom thick buffer layer.

It is submitted that a person skilled in the art would not modify Pessa or assume that the first two one atom thick layers would be satisfactory in view of Pessa teaching that many such layers are needed to accommodate the dislocations.

This is a simple case of the Examiner using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art.

Moreover, Applicant's Claim 1 recites "wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and

formation of dislocation defects." Based on the Examiner's rejections it is also not clear what would prompt a person, having ordinary skill in the art, to believe that a single atom layer in a degraded two atom thick buffer layer, supposedly disclosed in Pessa, would substantially accommodate strain accumulated between the first crystal and the second crystal. Of course a person of ordinary skill would not believe it since Pessa tells us that it does not happen.

Since Pessa teaches the use of many Ga and As one atom thick layers to obtain reduction in lattice strain. It is submitted that a person of ordinary skill in the art would draw from this that the strain relief is distributed over all of the layers. The Examiner's belief that the first one atom layer in Pessa substantially accommodates strain would seem to imply that the remaining layers accommodate essentially no strain. The Applicant believes that the Examiner's position is unorthodox and flies in the face of conventional notions of physics, in particular:

- 1) the strain relief is believed to occur uniformly if the thickness is greater than the so-called "Matthews Blakeslee critical thickness"; and
- 2) if the thickness is under the Matthews-Blakeslee critical thickness, then strain relief occurs with dislocations.

The Examiner failed to provide any evidence to support his beliefs, which the applicant believes are unorthodox, even when the applicant called upon the Examiner to cite some reference supporting his views. The Examiner also failed to comply with the rules of practice, particularly 37 C.F.R. 1.104(d)(2) and supply the Affidavit specifically setting forth the facts upon which he relies in rejecting Claim 1.

Further, Pessa's patent teaches away from the Applicant's invention. As the Examiner stated, the Pessa patent describes a buffer layer that "causes reduction in lattice strain by **creating mismatch dislocations**," see column 2, lines 35-40 in Pessa and see page 3, lines 1-3 of Office Action dated June 23, 2003. The Applicant submits that the current invention prevents strain relaxation and formation of dislocation defects thereby preventing mismatch dislocations.

An obstacle in realizing next-generation microelectronic and optoelectronic devices and optimal integration of these devices is found in lattice mismatches between different crystals of group III-V semiconductor materials. Generally, the lattice mismatches between a substrate and an epitaxial over-layer induce strains within the over-layer. This may lead to strain relaxation which can result in formation of material defects such as dislocations within the crystalline structure of the over-layer. The Applicant's Figure 1 illustrates a mismatched over-layer 1 epitaxially grown over a substrate 2, the boundary between the over-layer 1 and the substrate 2 being indicated with reference numeral 4. As shown in Figure 1, the lattice associated with over-layer 1 is different from the lattice constant associated with the substrate 2, hence the term "mismatched over-layer." Strain relaxation due to lattice mismatch is accommodated by the formation of mismatch dislocations 3 within the crystal. Defects within a crystal generally degrade the performance of devices made from the crystal. It is thus useful to provide means for growing a crystal over-layer which has a different lattice constant from the substrate on which the over-layer is grown, in such a fashion that strain relaxation does not occur and **mismatch dislocations do not form**. Applicant's Figure 2 is an example of a schematic representation of how lattice mismatch is taken by a condensed layer of group-V species, in which the structure of over-layer 1 is preserved and **no mismatch dislocations are formed**. Please refer to page 1, lines 9-21 and page 2, lines 1-4 of the

disclosure. The present invention answers the need for a method of growing a crystal over a substrate such that mismatch dislocations are substantially prevented from appearing within the crystal, even though the crystal and the substrate have different lattice constants, by suppressing strain relaxations associated with lattice-mismatches and preventing formation of dislocation defects, refer to page 3, lines 1-20 of the applicant's application.

Further regarding Claim 1, the Examiner asserts, in part, that Hayakawa teaches a GaAs substrate is heated to about 600°C during a radiation treatment by an As₄ molecular beam with about 10⁻⁶ to 10⁻⁵ torr and is allowed to stand at about 600°C for about 10 minutes, and after which the temperature of the GaAs substrate is lowered to 200°C or less during a radiation treatment by the As₄ molecular beam, thereby achieving complete removal of an oxidized film formed on the GaAs substrate and obtaining a GaAs substrate with a clean surface. The Examiner asserts that this reads on the Applicant's cleansing by thermal desorption and it would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Pessa with Hayakawa to clean the surface of the substrate to remove oxide from the surface.

The Applicant respectfully submits that the Examiner failed to fully consider that Pessa teaches away from Hayakawa, therefore, the Applicant's invention would not have been obvious to a person having ordinary skill in the art based on combined teachings of Pessa and Hayakawa.

According to Hayakawa "the deposited As is completely evaporated by a heating process prior to the subsequent epitaxial growth process," see column 4, lines 60-62 of Hayakawa. Hayakawa goes on to teach that "in order to grow high-quality crystals on

the substrate, the growth temperature is controlled as follows: The growth is started at a relatively low temperature in order to prevent as much deterioration of the GaAs substrate as possible resulting from the removal of As therefrom," see column 5, lines 11-16 of Hayakawa. Unlike Hayakawa, Pessa teaches that "the shutter 6 is opened in front of the As cell and the vapor beam (As_4 molecules) is allowed to act on the surface of the substrate 1 for a period of time which is required for the formation of one atom layer," see column 3, lines 40-44 of Pessa. It is unclear how the Examiner expects an ordinary person skilled in the art to combine Pessa and Hayakawa when Hayakawa teaches the complete removal of As while Pessa teaches the formation of multiple one atom thick As layers.

To summarize, based on Pessa's patent and Hayakawa's patent the Examiner failed to show how it would have been obvious to a person having ordinary skill in the art to conceive

"a method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the step of: cleansing a surface of the first crystal by thermal desorption; depositing a first layer of a first material over the surface of the first crystal; depositing a second layer of a second material over the first layer; and epitaxially growing the second crystal over the second layer; wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects"

as claimed in Claim 1, for the following reasons:

(1) The Examiner assumes that it would be obvious to use only two layers in Pessa however that is illogical since Pessa teaches not only the use of multiple layers, but also why multiple layers are needed.

(2) The Examiner assumes that a person having ordinary skill in the art would use only two of the multiple one atom thick layers of Ga and As, taught by Pessa, even though Pessa teaches of pure edge dislocations and a thick buffer layer to accommodate these dislocations.

(3) The Examiner mistakenly assumes that a single layer of the multiple one atom thick layers discussed in Pessa, is enough to "substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth," as claimed in Claim 1.

(4) Pessa patent teaches away from the Applicant's invention. Pessa specifically describes a buffer layer that causes reduction in lattice by creating mismatch dislocations. Where as Claim 1 states "first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects."

(5) The Examiner wrongfully combined the above references because Hayakawa patent teaches away from Pessa patent. Hayakawa teaches complete removal of As layer where as Pessa teaches the formation of multiple one atom thick As layers.

Therefore, the Applicant believes the Claim 1 is patentable over the cited references.

Claims 2-3

Regarding Claims 2-3, the Applicant submits that Claims 2-3 are patentable over Pessa and Hayakawa based upon their dependence on Claim 1. Further, the Applicant submits that the Examiner has not shown that Pessa and Hayakawa teach, discloses, or suggests "the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa" as recited in Claim 3. According to Hayakawa's preferred embodiment "GaAs substrate is

gradually heated to about 600°C during a radiation treatment by an As₄ molecular beam with about 10⁻⁶-10⁻⁵ torr," see column 4, lines 46-49 of Hayakawa. Pressure of 10⁻⁶-10⁻⁵ torr is roughly equivalent to 0.00013 - 0.0013 pa. The range of pressure taught by Hayakawa is much lower than the pressure range taught in Claim 3. The maximum pressure in Hayakawa (.0013 pa) is three times lower than the minimum pressure in Claim 3 (.004 pa).

The Examiner asserts that Hayakawa teaches As molecular beam pressure of 10⁻⁴-10⁻⁵ torr (0.013 to 0.0013 pa). The Applicant submits that Hayakawa teaches away from the use of As molecular beam pressure of 10⁻⁴-10⁻⁵ torr by using pressure of 10⁻⁶-10⁻⁵ torr in his preferred embodiment. In describing the background of the invention Hayakawa states that "during the process of removal of the oxidized film of GaAs, it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10⁻⁴-10⁻⁵ torr in a short time. Thus, it takes a long time for the removal of the oxidized film," see column 1, line 65 to column 2, line 2 of Hayakawa. The Applicant submits that Hayakawa used As molecular beam pressure of 10⁻⁶-10⁻⁵ torr in his preferred embodiment to lower the strength of the As molecular beam and to shorten the time for the removal of the oxidized film.

Therefore, the Applicant believes the Claims 2-3 are patentable over the cited references.

Claims 4-5 and 8-9

Regarding Claims 4-5 and 8-9, the Examiner asserts that Hayakawa in combination with Pessa teaches a GaAs substrate and an As₄ vapor. Although cited art teaches a GaAs

substrate and an As₄ vapor, it does not teach a GaP or InP crystal with InAs, P₂ or P₄ vapor as claimed in Claim 5.

Further, Claims 4-5 and 8-9 directly or indirectly depend from Claim 1, they are believed to be patentable over the cited references.

Further, Claims 4-5 directly or indirectly depend from Claim 3, they are believed to be patentable over the cited references.

Claim 6

Regarding Claim 6, the Applicant submits that Claim 6 is patentable over Pessa and Hayakawa at least based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has not shown that Pessa and Hayakawa teach, discloses, or suggests “adjusting a thickness of the first layer by varying a temperature of the first crystal” as recited in Claim 6. The Examiner asserts that Hayakawa in combination with Pessa teaches removing excess arsenic by re-evaporation, so the growing surface grows by only one atom layer at a time, and this reads on adjusting the thickness by varying a temperature of the first crystal. Once again the Examiner is not quoting the exact and complete language of the Pessa patent, thereby changing the meaning of what Pessa is trying to teach. Accordingly, Pessa teaches removing excess arsenic through re-evaporation, and the growing surface grows by one atom layer only. After this time period (of the order of 1 sec), the shutter 6 is closed and the shutter 5 is opened, see column 3, lines 45-49. This seems to mean that shutter 6 is opened for a specified time period until the arsenic is removed through re-evaporation and the surface grows by one atom layer only. Unlike in Claim 6, Pessa does not teach changing the temperature to

adjust the thickness of the first layer. On the contrary, the time period of how long the shutter 6 is open is used to adjust the thickness of the layer. Further, Pessa does not teach how to adjust the thickness if the layer is more than one atom thick. On the contrary, according to Pessa "the growing surface grows by one atom layer only," see column 3, lines 47-48 of Pesa. In the specification the Applicant specifically teaches that the As₂ condensed layer can be thinned down to the desired thickness by raising the temperature of the substrate to about 250°C, see page 10, lines 10-12.

Therefore, the Applicant believes the Claim 6 is patentable over the cited references.

Claim 7

Regarding Claim 7, the Applicant submits that Claim 7 is patentable over Pessa and Hayakawa based upon its dependence on Claims 1 and 6.

Claim 10 and 30

Regarding Claims 10 and 30, the Applicant submits that Claim 10 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1. The Applicant submits that Claim 30 is patentable over Pessa and Hayakawa based upon its dependence on Claim 27.

Claim 11

Regarding Claim 11, the Applicant submits that Claim 11 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1.

Claims 25-26

Regarding Claims 25-26, the Applicant submits that Claims 25-26 are patentable over Pessa and Hayakawa based upon their dependence on Claim 1.

Claim 27

Regarding Claim 27, the same argument applies as for Claim 1. Therefore, the Applicant believes that Claim 27 is patentable over the cited references.

Claim 29 and 39-40

Regarding Claims 29 and 40, the Applicant submits that Claims 29 and 40 are patentable over Pessa and Hayakawa based upon their dependence on Claim 27. Regarding Claim 39, the Applicant submits that Claim 39 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1.

Claim 31

Regarding Claim 31, the Applicant submits that Claim 31 is patentable over Pessa and Hayakawa based upon its dependence on Claim 27.

Issue 2: Whether Claims 12 - 16 and 18 - 22 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and further in view of Ogasawara U.S. Patent No. 4,897,367 (hereinafter “Ogasawara”)?

In section 3 of the Office Action of June 23, 2003, the Examiner rejects Claims 12-16 and 18-22 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa as applied to Claims 1-11, and further in view of Ogasawara. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Ogasawara teaches a process of growing Gallium Arsenide (GaAs) on a Silicon Substrate (Si). Silicon belongs to group-IV species unlike the group III-V species substrate claimed in the present application. As a person of ordinary skill in the art knows group-IV species have different characteristics and properties from group III-V species, therefore, it is not clear what a person familiar with Pessa and Hayakawa would gain from Ogasawara. A person of ordinary skill in the art would not look to group-IV species art when trying to improve group III-V crystal growth. It is the Applicant's belief that the only reason Ogasawara was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Ogasawara is non-analogous art and a person trying to improve group III-V crystal growth would not look to it. Also, the Examiner utterly failed to show any motivation for a person skilled in the art to combine these references. Thus claims 12-16 and 18-22 are patentable over the cited references.

Claim 12

Regarding Claim 12, the Applicant submits that Claim 12 is patentable over Pessa, Hayakawa and Ogasawara, at least based upon its dependence on Claim 1 and Claim 6. Moreover, in addition to Pessa being incompatible with Hayakawa, Applicant does not understand what the motivation is (or the effect of) combining these two disclosures with Hayakawa. Furthermore, the Applicant submits that the Examiner has not shown that Pessa, Hayakawa and Ogasawara teach, disclose, or suggest “annealing the second layer ... under a pressure of the first vapor of about 0.008 pa” as recited in Claim 12. Pessa teaches that first layer As is deposited on the substrate by opening shutter 6, then shutter 6 is closed and a second layer Ga is deposited by opening shutter 5, then again shutter 5 is closed and a third layer As is deposited by opening shutter 6, and so on until the desired buffer layer is completed, see column 3, lines 31-65. As the Examiner admits Pessa and Hayakawa do not teach annealing the second layer by raising the temperature of the first crystal under a pressure of the first vapor of about 0.008 pa, see page 6 lines 1-2 of the Office action dated June 23, 2003. Similarly, Ogasawara does not provide at what pressure the As is to be released onto the substrate, see column 2, lines 55-68. Therefore, it would not have been obvious to a person having ordinary skill in the art to combine Pessa, Hayakawa and Ogasawara or keep the pressure of the first vapor at 0.008 pa. The Applicant submits that Claim 12 is patentable over the cited art.

This is another example of the Examiner using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art. Further, the Examiner failed to show motivation to combine these references in the matter set forth in his Office Actions. The Examiner is using

hindsight to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task for one skilled in the art.

Claim 13

Regarding Claim 13, the Applicant submits that Claim 13 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 12. The Applicant submits that Claim 13 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that Ogasawara teaches introducing a Ga flux to form a Ga monolayer. The Applicant submits that the Examiner is mistaken. According to Ogasawara "a Ga beam is irradiated onto the substrate 1 in an amount needed to form a GaAs layer and thus the first GaAs layer is formed," see column 2, lines 43-45 of Ogasawara. Contrary to the Examiner, Ogasawara does not teach, disclose or suggest the formation of Ga monolayer. Ogasawara teaches the formation of first GaAs layer followed by Si layer, see Figure 1 of Ogasawara.

Once again the Examiner is using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art. The Examiner is using hindsight to combine a large number of references in a complex matter to arrive allegedly at the claimed invention. The combination proposed by the Examiner is not logical for the reasons stated and there is certainly no motivation for making the suggested combination.

Claim 14

Regarding Claims 14, the Applicant submits that Claim 14 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 15

Regarding Claims 15, the Applicant submits that Claim 15 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that the combination of Pessa, Hayakawa and Ogasawara teaches a GaAs first crystal, an As first material and a Ga second material. The Examiner is using hindsight to try to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task, if not an impossible task, for one skilled in the art. As stated above Ogasawara teaches a process for growing GaAs on Si substrate, contrary to the Examiner's assertion that it teaches a GaAs first crystal.

Additionally, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 16

Regarding Claims 16, the Applicant submits that Claim 16 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that the combination of Pessa, Hayakawa and Ogasawara teaches a GaAs first crystal, a first material of As₄ and a second material Ga. The Examiner is using hindsight to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task for one skilled in the art. As stated above Ogasawara teaches a process for growing GaAs on Si substrate, contrary to the Examiner's assertion that it teaches a GaAs first crystal.

Also, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claims 18-22

Regarding Claims 18-16, the Applicant submits that Claims 18-16 are patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Issue 3: Whether Claims 17 and 23 - 24 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and further in view of Grunthaner et al., U.S. Patent No. 5,094,974 (hereinafter "Grunthaner")?

In section 4 of the Office Action of June 23, 2003, the Examiner rejects Claims 17 and 23-24 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa and Ogasawara as applied to Claims 12-16 and 21-22, and further in view of Grunthaner. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Grunthaner teaches growth of III-V films by control of MBE growth front stoichiometry. Unlike Pessa, Grunthaner "grow[s] an extensive GaAs buffer layer of 1 to 2 micrometers thickness," see column 4, lines 42-44 of Grunthaner. That translates to a minimum and maximum thickness of 10,000 Å to 20,000 Å, well above the thickness of two atom thick buffer layer the Examiner alleges is taught by Pessa. How does the Examiner justify combining these two references? In rejecting Claim 1 above the Examiner used Pessa to allege that the two, of many, one atom thick layers taught in Pessa read on Claim 1. Now the Examiner combines Pessa with

Grunthaner. The Examiner should not consider a thin buffer layer when rejecting Claim 1 and a thick buffer layer when rejecting Claims 17 and 23-24 that are dependent on Claim 1. The Examiner used Applicant's claims as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. It is the Applicant's belief that the only reason Grunthaner was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Grunthaner is non-analogous art and the Examiner utterly failed to show any motivation for a person skilled in the art to combine Pessa with Grunthaner. Thus Claims 17 and 23-24 are patentable over the cited references.

Claims 23-24

Regarding Claims 23-24, the Applicant submits that Claims 23-24 are patentable over Pessa, Hayakawa Ogasawara and Grunthaner based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Moreover, according to the Examiner Pessa, Hayakawa and Ogasawara fail to teach the ratio of the group V flux to the group III flux is substantially in the range of about 1.5 to about 3. The Examiner asserts that in a method of growing group III-V film by control of MBE growth stoichiometry, Grunthaner teaches instantaneous flux ratios of In to As have been critical to the control of defect generation in the lattice mismatched epitaxy of InAs on GaAs. The Examiner further asserts that it would have been obvious to a person of ordinary skill in the art to modify

the combination Pessa, Hayakawa and Ogasawara with Grunthaner by optimizing the ratio of group V flux to the group-III flux substantially in the range of 1.5 to about 3 by conducting routine experimentation. The Applicant respectfully disagrees with the Examiner's assertions. Although Grunthaner recognizes that "flux ratios of In to As have been critical to the control of defect generation in the lattice mismatched epitaxy of InAs on GaAs substrates," see column 2, lines 30-33, the Applicant submits that Grunthaner's approach to determining the flux ration would not have yield the range of 1.5 to about 3 through routine experimentation. According to Grunthaner, "by introducing small delay times in the relative opening sequence of shutter operation program, ... [Grunthaner] could control the effective In to As ratio throughout the monolayer growth cycle," see column 2, lines 43-47. By varying "the appropriate delays between In, As and Ga shutters ... [Grunthaner] found a strong variation in the converge or quality of the InAs film," see column 3, lines 3-5. Basically Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike Claim 23, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 17

Regarding Claim 17, the Applicant submits that Claim 17 is patentable over Pessa, Hayakawa Ogasawara and Grunthaner based upon its dependence on Claim 1 and Claim 16. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has

not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Moreover, the Examiner asserts that the selection of reaction parameters such as temperature and concentration is obvious and the ration of fluxes is a result effective variable as taught by Grunthaner. As discussed above with reference to Claims 23 and 24, Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike present application, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Issue 4: Whether Claims 32 - 33 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and Grunthaner and further in view of Kubiak et al., U.S. Patent No. 4,330,360 (hereinafter “Kubiak”)?

In section 5 of the Office Action of June 23, 2003, the Examiner rejects Claims 32-33 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa, Ogasawara and Grunthaner as applied to Claims 17 and 23, and further in view of Kubiak. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner

shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Kubiak teaches molecular beam deposition technique using gaseous sources of group V elements. Kubiak's discloses "a method and apparatus for growing ... group III-V semiconductor layers on a semiconductor body ... by molecular beam deposition. The group III-V semiconductor layer is formed by directing a group III molecular beam and a group V molecular beam at a semiconductor body," see column 2, lines 10-17. Unlike Pessa, Kubiak does not teach the use of a thick buffer layer between the group III-V semiconductor layers and a semiconductor body. Once again, how does the Examiner justify combining these two references? In rejecting Claim 1 above the Examiner used Pessa to allege that the two, of many, one atom thick layers taught in Pessa read on Claim 1. Now the Examiner combines Pessa with Kubiak. The Examiner should not consider a buffer layer when rejecting Claim 1 and no buffer layer when rejecting Claims 32-33. The Examiner used Applicant's claims as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. It is the Applicant's belief that the only reason Kubiak was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Kubiak is non-analogous art and the Examiner utterly failed to show any motivation for a person skilled in the art to combine Pessa with Kubiak.

The Examiner is using hindsight to combine a large number of references in a complex matter to arrive allegedly at the claimed invention. The combination proposed by the Examiner is not logical from the reasons stated and there is certainly no motivation for

making the suggested combination. Thus Claims 32-33 are patentable over the cited references.

Claim 32

Regarding Claim 32, the Examiner asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach all of the limitations of Claim 32 including heating a substrate to 600°C and annealing under a pressure of As₄ vapor, which is equivalent to As₂ of 10⁻⁴ to 10⁻⁵ torr (0.013 to 0.0013 pa). The Applicant strongly disagrees with the Examiner's assertion. Once again the Examiner is improperly quoting prior art. Although Hayakawa teaches applying As₄ to the substrate the actual pressure range is 10⁻⁵ to 10⁻⁶ torr (0.0013 to 0.00013 pa), the pressure disclosed in Claim 32 is 0.008 pa. which is not in the range specified by Hayakawa.

The Examiner further asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach growing one arsenic atom layer and removing excess arsenic through re-evaporation, where the evaporation temperature of As is on the order of 300°C. Unfortunately, the Examiner is once again not paying close attention to what is taught in the prior art. Accordingly, Pessa teaches removing excess arsenic through re-evaporation, and the growing surface grows by one atom layer only. After this time period (of the order of 1 sec), the shutter 6 is closed and the shutter 5 is opened, see column 3, lines 45-49. This seems to mean that shutter 6 is opened for a specified time period until the arsenic is removed through re-evaporation and the surface grows by one atom layer only. Unlike in Claim 6, Pessa does not teach changing the temperature to adjust the thickness of the first layer. Further, Pessa does not teach how to adjust the thickness if the layer is more than one atom thick. On the contrary, according to Pessa "the growing surface grows by

one atom layer only," see column 3, lines 47-48 of Pessa. In Claim 32 the Applicant specifically teaches "adjusting the thickness of the condensed layer of As_2 by raising the temperature of the substrate to about 250°C , thereby thinning the condensed layer of As_2 to several tens of \AA ."

The Examiner goes on to assert that Pessa, Hayakawa, Ogasawara, and Grunthaner teach that it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10^{-4} to 10^{-5} torr in a short time, therefore As used in the growth chamber is present during growth of compound semiconductors, and this reads on the Applicant's subjecting the substrate to an As_2 vapor pressure of about 0.008 pa for forming a monolayer if In atoms. As stated above, the Applicant submits that Hayakawa teaches away from the use of As molecular beam pressure of 10^{-4} - 10^{-5} torr by using pressure of 10^{-6} - 10^{-5} torr in his preferred embodiment. In describing the background of the invention Hayakawa states that "during the process of removal of the oxidized film of GaAs, it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10^{-4} - 10^{-5} torr in a short time. Thus, it takes a long time for the removal of the oxidized film," see column 1, line 65 to column 2, line 2 of Hayakawa. The Applicant submits that Hayakawa used As molecular beam pressure of 10^{-6} - 10^{-5} torr in his preferred embodiment to lower the strength of As molecular beam and to shorten the time for the removal of the oxidized film.

Since Hayakawa teaches that As_2 molecular beam is 10^{-5} to 10^{-6} torr (0.0013 to 0.00013 pa), column 4, lines 45-50, it is nowhere near 0.008 pa recited in Claim 32. Also, Hayakawa teaches that the substrate is exposed to As_4 for removal of the oxidized film in the pre-treatment chamber 3. Upon completion of removal of the oxidized film the substrate is carried to the growth chamber 4, see column 3, lines 45-60 and column 4,

lines 3-5. Contrary to the Examiner's assertion none of the prior art teaches "introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As₂ vapor pressure of about 0.008 pa; and raising the temperature of the substrate to about 400°C while the As₂ vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer."

The Examiner further asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach that the buffer layer reduces dislocations between the substrate and the epitaxial layer, and it reads on the Applicant's epitaxial growth does not introduce dislocation defects caused by lattice mismatch. As discussed above for Claim 1, Applicant's invention teaches away from the Pessa patent. As the Examiner stated the Pessa patent describes a buffer layer that "causes reduction in lattice strain by **creating mismatch dislocations**," see column 2, lines 35-40 in Pessa and see page 3, lines 1-3 of Office Action dated June 23, 2003. The Applicant submits that the current invention prevents strain relaxation and formation of dislocation defects thereby preventing mismatch dislocations.

The Examiner also asserts that the combination of Pessa, Hayakawa, Ogasawara, and Grunthaner is silent to introducing In vapor at a temperature of about 790°C. According to the Examiner, Kubiak teaches nominal effusion cell temperature s range from 900°C-1000°C for Ga and 800°C-840°C for In. The Examiner asserts that it would have been obvious to a person of ordinary skill in the art to modify the combination of of Pessa, Hayakawa, Ogasawara, and Grunthaner with Kubiak by optimizing the effusion cell temperature by conducting routine experimentation of result effective variables. It seems like the Examiner used Claim 32 as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. As stated above, Kubiak does not teach the use of two

layers between the group III-V semiconductor layers and a semiconductor body. A person of ordinary skill in the art would not look to the art teaching depositing group III-V semiconductor layers directly on a semiconductor body when trying to improve crystal growth with two layers between the crystals. It is the Applicant's belief that the only reason Kubiak was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Kubiak is non-analogous art and a person trying to improve crystal growth with two layers between the crystals would not look to it. Also, the Examiner utterly failed to show any motivation for a person skilled in the art to combine these references.

The Examiner failed to demonstrate that by reading cited prior art it would have been obvious to a person having ordinary skill in the art to come up with

"A method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of: a) extracting surface oxides from a surface of the substrate by thermal desorption, the thermal desorption including the steps of: a1) heating the substrate to a temperature of about 600°C; and a2) annealing the substrate for about 10 minutes under a pressure of As₂ vapor of about 0.008 pa; b) depositing a condensed layer of As₂ on the surface of the substrate, depositing a condensed layer including the steps of b1) lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As₂ vapor pressure of about 0.008 pa, whereby a condensed layer of As₂ is formed on the surface of the substrate; and b2) adjusting the thickness of the condensed layer of As₂ by raising the temperature of the substrate to about 250°C, thereby thinning the condensed layer of As₂ to several tens of Å; and c) depositing a mono-layer of In atoms over the condensed layer of As₂ the depositing a mono-layer comprising the steps of c1) introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As₂ vapor pressure of about 0.008 pa; and c2) raising the temperature of the substrate to about 400°C while the As₂ vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer; wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not

introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer"

as claimed in Claim 32. Therefore, the Applicant believes the Claim 32 is patentable over the cited references.

Claim 33

Regarding Claim 33, the Applicant submits that Claim 33 is patentable over Pessa, Hayakawa Ogasawara, Grunthaner and Kubiak based upon its dependence on Claim 32. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Additionally, the Examiner agrees that the combination of Pessa, Hayakawa Ogasawara, Grunthaner and Kubiak does not teach a ratio of flux is maintained at 2.5. According to the Examiner, the selection of reaction parameters such as temperature and concentration is obvious. The Applicant strongly disagrees with the Examiner's assertions. As discussed above, Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike present application, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Conclusion

For the extensive reasons advanced above, Appellant respectfully contends that each claim is patentable. Therefore, reversal of all rejections and objections is courteously solicited.

The Commissioner is authorized to charge any additional fees which may be required or credit overpayment to deposit account no. 12-0415. In particular, if this Appeal Brief is not timely filed, the Commissioner is authorized to treat this response as including a petition to extend the time period pursuant to 37 CFR 1.136(a) requesting an extension of time of the number of months necessary to make this response timely filed and the petition fee due in connection therewith may be charged to deposit account no. 12-0415.

I hereby certify that this correspondence is being deposited with the United States Post Office with sufficient postage as express mail in an envelope addressed to: Mail Stop Appeal Brief - Patents, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22323-1450 on

December 22, 2003

(Date of Mailing)

Corinda Humphrey

(Name of Person Mailing)

Corinda Humphrey

(Signature)

12-22-03

(Date)

Respectfully submitted,

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1. A method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the steps of:

- a) cleansing a surface of the first crystal by thermal desorption;
- b) depositing a first layer of a first material over the surface of the first crystal;
- c) depositing a second layer of a second material over the first layer; and
- d) epitaxially growing the second crystal over the second layer;

wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects.

2. The method of claim 1, wherein the step a) of cleansing the surface of the first crystal by thermal desorption includes the steps of:

- a1) bringing a temperature of the first crystal to T_s °C, T_s ranging from about 495°C to about 600°C;
- a2) introducing a desorption vapor having a desorption vapor pressure; and
- a3) annealing the first crystal under the desorption vapor pressure at temperature T_s ;

wherein the desorption vapor pressure is greater than a vapor pressure of the first crystal at temperature T_s .

3. The method of claim 2, wherein the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa, and wherein surface oxides of the first crystal are desorbed.

-
4. The method of claim 3, wherein the first crystal comprises group-III/group-V species, and the desorption vapor comprises group-V species.
 5. The method of claim 4, wherein the first crystal comprises GaAs, GaP, InAs or InP, and wherein the desorption vapor comprises As₂ or As₄ if the first crystal is GaAs or InAs, or the desorption vapor comprises InAs, P₂ or P₄ if the first crystal is GaP or InP.
 6. The method of claim 2, wherein the step b) of depositing a first layer includes the steps of:
 - bl) introducing a first vapor of the first material, wherein part of the first vapor condenses on the surface of the first crystal, thereby forming the first layer; and
 - b2) adjusting a thickness of the first layer by varying a temperature of the first crystal.
 7. The method of claim 6, wherein the first vapor is introduced at a temperature which is less than an optimal growth temperature for epitaxy.
 8. The method of claim 7, wherein the first crystal comprises group-III/group-V species, and the first material comprises group-V species.
 9. The method of claim 8, wherein the first crystal comprises GaAs, GaP, InAs or InP, and the first material comprises As₂, As₄, P₂ or P₄.
 10. The method of claim 9, wherein the thickness of the first layer ranges from approximately a few Å to approximately a few tens of Å.

11. The method of claim 10, wherein the step b1) of introducing a first vapor of the first material, includes the step of opening a first shutter blocking a growth chamber from a first vapor source.

12. The method of claim 6, wherein the step c) of depositing a second layer of a second material includes the steps of:

c1) introducing the second vapor, a temperature of the first crystal being maintained at T_d within a range of about 30°C to about 250°C , wherein at least part of the second vapor condenses over the first layer;

c2) annealing the second layer by raising the temperature of the first crystal from T_d to a temperature of about 400°C to about 580°C , under a pressure of the first vapor of about 0.008 pa.

13. The method of claim 12, wherein an amount of the second vapor introduced is such that the second layer is formed by a mono-layer of atoms of the second material.

14. The method of claim 13, wherein the step c1) of introducing the second vapor comprises the steps of:

c11) providing a furnace containing a second vapor of the second material;

c12) opening a second shutter allowing the second vapor to travel from the furnace to a growth chamber;

wherein the second shutter is opened for a predetermined time duration, whereby to allow a predetermined amount of the second vapor to travel from the furnace to the growth chamber, the predetermined amount of the second vapor being determined by the number of atoms of the second material necessary to form a mono-layer of said atoms over the first layer.

15. The method of claim 14, wherein the first crystal comprises group-III/group-V species, the first material comprises group-V species, and the second material comprises group-III species.

16. The method of claim 15, wherein the first crystal is selected from the group consisting of GaAs, GaP, InAs and InP, the first material is selected from the group consisting of As₂, As₄, P₂ and P₄, the second material is selected from the group consisting of In, Ga and Al or any combination thereof, and wherein the second vapor has a pressure of about 5×10^{-5} pa, the second vapor has a temperature of about 780°C if the second material is In, the second vapor has a temperature of about 900°C if the second material is Ga, the second vapor has a temperature of about 1200°C if the second material is Al.

17. The method of claim 16, wherein for the second material, combinations of Ga, Al, and In, are in a relative ratio substantially equal to the ratio of elements forming the second crystal which is to be epitaxially grown.

18. The method of claim 16, wherein the second shutter is opened for a time duration ranging from about 1 second to about 3 seconds.

19. The method of claim 18, wherein a number per surface area of group-III atoms forming the mono-layer is about $6.5 \times 10^{14} \text{ cm}^{-2}$ and wherein the second shutter is opened for 2.2 seconds.

20. The method of claim 16, wherein the thickness of the first layer ranges from a few Å to a few tens of Å.

21. The method of claim 12, wherein the second crystal is a group-III/group-V crystal and wherein the step d) of epitaxially growing the second crystal includes the steps of:

- d1) introducing group-III species into a growth chamber;
- d2) introducing group-V species into the growth chamber;
- d3) maintaining a temperature inside the growth chamber near an optimal temperature for epitaxial growth of the second crystal.

22. The method of claim 21, wherein the group-V species is introduced by opening a first shutter whereby to let a group-V flux into the growth chamber, and the group-III species is introduced by opening a second shutter whereby to let a group- III flux into the growth chamber.

23. The method of claim 22, wherein the ratio of the group-V flux to the group-III flux is substantially in the range of about 1.5 to about 3.

24. The method of claim 23, wherein the second crystal is selected from the group consisting of InAs, $\text{In}_x\text{Ga}_{1-x}\text{As}$, $\text{In}_x\text{Al}_{1-x}\text{As}$ or GaP.

25. The method of claim 1, wherein the method is used to manufacture semiconductor devices.

26. The method of claim 25, wherein the method is used in microelectronic and optoelectronic applications.

27. A method of preparing a substrate for subsequent epitaxial growth of a crystal over the substrate, the method comprising the steps of:

- a) cleansing a surface of the substrate by thermal desorption;

b) depositing a first layer of a first material over the surface of the substrate; and

c) depositing a second layer of a second material over the first layer, wherein the crystal is deposited over the second layer, wherein the first layer accommodates strain accumulated between the substrate and the crystal during epitaxial growth, thereby preventing strain relaxation and formation of dislocation defects.

28. (Cancelled)

29. The method of claim 27 wherein:

the substrate comprises group-III/group-V species;

the crystal comprises group-III/group-V species;

the first material comprises group-V species; and

the second material comprises group-III species.

30. The method of claim 29, wherein the first layer has a thickness within a range of approximately a few Å to a few tens of Å.

31. The method of claim 30, wherein the second layer is a monolayer of group-III atoms.

32. A method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of:

a) extracting surface oxides from a surface of the substrate by thermal desorption, the thermal desorption including the steps of:

al) heating the substrate to a temperature of about 600°C; and

a2) annealing the substrate for about 10 minutes under a pressure of As_2 vapor of about 0.008 pa;

b) depositing a condensed layer of As_2 on the surface of the substrate, depositing a condensed layer including the steps of:

b1) lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As_2 vapor pressure of about 0.008 pa, whereby a condensed layer of As_2 is formed on the surface of the substrate; and

b2) adjusting the thickness of the condensed layer of As_2 by raising the temperature of the substrate to about 250°C , thereby thinning the condensed layer of As_2 to several tens of Å; and

c) depositing a mono-layer of In atoms over the condensed layer of As_2 the depositing a mono-layer comprising the steps of:

c1) introducing In vapor at a temperature of about 790°C , the temperature of the substrate being maintained around 250°C and being subjected to an As_2 vapor pressure of about 0.008 pa; and

c2) raising the temperature of the substrate to about 400°C while the As_2 vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer; wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer.

33. The method of claim 32, further comprising the step d) of epitaxially growing the InAs layer, the step d) including the steps of:

d1) introducing a flux of In vapor;

d2) introducing a flux As vapor; and

d3) maintaining the temperature of the substrate between about 400°C and about 450°C; wherein the ratio of the flux of As vapor to the flux of In vapor is maintained at about 2.5.

34 (Withdrawn)

35 (Withdrawn)

36 (Withdrawn)

37 (Withdrawn)

38 (Withdrawn)

39. The method of claim 1, wherein the first crystal comprises the first material of the first layer and the second crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species.

40. The method of claim 27, wherein the first crystal comprises the first material of the first layer and the crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species.



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Binqiang Shi)	On Appeal to the
)	Board of Appeals
Patent Application No.: 09/851,839)	
)	Group Art Unit: 1765
Filed: May 9, 2001)	
)	Examiner: Nadine G. Norton
)	
For: "NOVEL EPITAXY WITH COMPLIANT)	
LAYERS OF GROUP-V SERIES")	Date: December 22, 2003
)	

BRIEF ON APPEAL

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This is an appeal from the Final rejection, dated October 9, 2003, for the above identified patent application. The Applicant submits that this Appeal Brief is being timely filed, since the notice of Appeal was filed on October 20, 2003.

REAL PARTY IN INTEREST

The present application has been assigned to HRL Laboratories, LLC of Malibu, CA.

STATUS OF CLAIMS

Claims 1 - 27, 29-33 and 39-40 are the subject of this Appeal and are reproduced in the accompanying appendix. The Examiner has withdrawn Claims 34 - 38 from consideration. Claim 28 has been canceled.

STATUS OF AMENDMENTS

No Amendment After Final Rejection has been entered.

SUMMARY OF INVENTION

The invention described and claimed in the present application relates to the process or method of growing of a group III-V crystal on top of another group III-V crystal (substrate), without introducing lattice-mismatch defects.

The method comprising the steps of: thermal desorption cleansing of the substrate; in situ introduction of condensed group-V species; deposit of a mono-layer of group-III atoms on the group-V layer; and epitaxial growth of crystal over the mono-layer (see in particular claims 1, 27 and 32).

As a consequence, strain relaxation associated with lattice-mismatched epitaxy is suppressed there by preventing formation of dislocation defects (see specification, page 3 lines 9-17).

A preferred embodiment of the method of growing of a group III-V crystal on top of another group III-V crystal (substrate) is depicted in Figures 3-6.

Figure 3 shows a step of thermal desorption cleansing of the substrate. More specifically, substrate 7 is first heated inside a growth chamber 6, to temperature T_s , where T_s ranges from about 495°C to about 600°C. Vapor 8 comprising group-V species is introduced in the growth

chamber 6, through gate 19, when substrate 7 is heated. The pressure P of the vapor 8 may range from about 0.004 pa to about 0.012 pa, pressure P is larger than the vapor pressure P_s of the substrate 7 at temperature T_s . The temperature of the vapor 8 may range from about 300°C to about 1000°C. The substrate 7 is then annealed under this over-pressure of group-V species vapor, at temperature T_s , and desorption of surface oxides 9 from the substrate 7 takes place, with the surface oxides being removed from chamber by pump 20. See page 6 of the specification.

Figure 4 shows a step of in situ introduction of condensed group-V species. More specifically, in this step a vapor 13 comprising a group-V species is introduced onto surface of the substrate by opening shutter 19. When the temperature T_s of the substrate 7 is appropriately low, between about 30°C and about 250°C, and the pressure P_c of the group-V vapor 13 is adequate, about 0.004 pa to about 0.012 pa, condensation of the group-V species on the substrate 7 takes place. The thickness of the layer 11 of group-V species can be controlled by varying the temperature T_s of the substrate 7. The amount of desorption from the condensed layer of group-V species is dependent on the temperature. In other words, different thicknesses of the layer 11 can be achieved by varying the temperature T_s . The temperature T_s of the substrate 7 is preferably set such that the thickness of the layer of the group-V species falls into a range of several Å to a few tens of Å. See pages 6-7 of the specification.

Figure 5 shows a step of depositing a mono-layer of group-III atoms on the group-V layer. More specifically, in this step a vapor of group-III atoms 17 is introduced in the growth chamber 6, wherein the vapor 17 condenses on the surface of the substrate 7 above the layer of group-V atoms 11, forming a mono-layer of group-III atoms 12. The vapor 17 is introduced at temperatures ranging from about 780°C to about 1250°C and at a pressure of about 5×10^{-5} pa. The layer 12 may have a thickness ranging from one atom to a few atoms. As vapor 17

condenses over layer 11, the substrate 7 is kept at a temperature T_d ranging from about 30°C to about 250°C and the pressure of the group-V vapor 13 is maintained around 0.008 pa. The layer 12 is then annealed by raising the temperature of the substrate T_d to a temperature from about 400°C to about 580°C, under a pressure of group-V vapor 13 of about 0.008 pa. Such mono-layer of group-III atoms 12 has the property of changing the desorption tendency of the group-V species layer 11 lying underneath, and allows retention of the group-V species layer 11 during the annealing phase, which precedes the actual epitaxial growth of the crystal at an optimal growth temperature. The group-III atoms in the mono-layer 12 will seek lattice sites of a lower free energy during annealing, and will therefore form a propitious starting atomic plane for subsequent epitaxial growth. Because the bonding between group-V molecules in layer 11 is much weaker than that between atoms of the solid crystal to be grown, the group-V molecules will relocate during the subsequent epitaxy to accommodate the lattice mismatch between the solid substrate crystal 7 and the desired solid crystal to be grown over layer 12. See pages 7-9 of the specification.

Figure 6 shows a step of epitaxial growth of crystal over the mono-layer. More specifically, in this step growth of bulk group III-V species layer 18 is initiated by reopening the shutter 14 of the group-III furnace 15. In the preferred embodiment, group-V species and group-III species are introduced in the growth chamber with the ration of the group-V flux to the group-III flux being maintained in the range of about 1.5 to about 3. See page 9 of the specification.

Overview of independent Claims 1, 27 and 32

This embodiment of the method of growing of a group III-V crystal on top of another group III-V crystal (substrate), without introducing lattice-mismatch defects is exemplified in independent Claims 1, 27 and 32.

Independent Claim 1 claims a method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the step of: cleansing a surface of the first crystal by thermal desorption (as described with reference to Figure 3); depositing a first layer of a first material over the surface of the first crystal (as described with reference to Figure 4); depositing a second layer of a second material over the first layer (as described with reference to Figure 5); and epitaxially growing the second crystal over the second layer (as described with reference to Figure 6); wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects.

Independent Claim 27 claims a method of preparing a substrate for subsequent epitaxial growth of a crystal over the substrate, the method comprising the steps of: cleansing a surface of the substrate by thermal desorption (as described with reference to Figure 3); depositing a first layer of a first material over the surface of the substrate (as described with reference to Figure 4); and depositing a second layer of the second material over the first layer (as described with reference to Figure 5), wherein the crystal is deposited over the second layer (as described with reference to Figure 6), wherein the first layer accommodates strain accumulated between the substrate and the crystal during epitaxial growth, thereby preventing strain relaxation and formation of dislocation defects.

Finally, independent Claim 32 claims a method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of: a) extracting surface oxides from a surface of the substrate by thermal desorption (as described with reference to Figure 3), the thermal desorption including the steps of: heating the substrate to a temperature of about 600°C (as described on page 10 of the specification); and annealing the

substrate for about 10 minutes under a pressure of As_2 vapor of about 0.008 pa (as described on page 10 of the specification); b) depositing a condensed layer of As_2 on the surface of the substrate (as described with reference to Figure 4), depositing a condensed layer including the steps of: lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As_2 vapor pressure of about 0.008 pa, whereby a condensed layer of As_2 is formed on the surface of the substrate (as described on page 10 of the specification); and adjusting the thickness of the condensed layer As_2 by raising the temperature of the substrate to about 250°C , thereby thinning the condensed layer of As_2 to several tens of Å (as described on page 10 of the specification); and c) depositing a mono-layer of In atoms over the condensed layer As_2 (as described with reference to Figure 5), the depositing a mono-layer comprising the steps of: introducing In vapor at a temperature of about 790°C , the temperature of the substrate being maintained around 250°C and being subjected to an As_2 vapor pressure of about 0.008 pa (as described on pages 10-11 of the specification); and raising the temperature of the substrate to about 400°C while the As_2 vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer (as described on pages 10-11 of the specification); wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer.

Overview of dependent claims 2-26, 29-31, 33, 39 and 40

Claim 2 depends on Claim 1. Dependent Claim 2 recites that the step of cleansing the surface of the first crystal by thermal desorption of Claim 1 includes the steps of bringing a temperature of the first crystal to $T_s^\circ\text{C}$, T_s ranging from about 495°C to about 600°C (see page 6, lines 9-10 of the specification); introducing a desorption vapor having a desorption vapor pressure (see page 6, lines 10-14 of the specification); and annealing the first crystal under the desorption vapor

pressure at temperature T_s (see page 6, lines 15-18 of the specification); wherein the desorption vapor pressure is greater than a vapor pressure of the first crystal at temperature T_s (see page 6, lines 10-15 of the specification).

Claim 3 depends from Claim 2. Dependent Claim 3 recites that the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa and wherein surface oxides of the first crystal are desorbed (see page 6, lines 10-18 of the specification).

Claim 4 depends from Claim 3. Dependent Claim 4 recites that the first crystal comprises group-III/Group-V species, and the desorption vapor comprises group-V species (see page 6, lines 5-7 and 15-18 of the specification).

Claim 5 depends from Claim 4. Dependent Claim 5 recites that the first crystal comprises GaAs, GaP, InAs or InP, and wherein the desorption vapor comprises As_2 or As_4 if the first crystal is GaAs or InAs, or the desorption vapor comprises InAs, P_2 or P_4 if the first crystal is GaP or InP (see page 6, lines 5-7 and 10-11 of the specification).

Claim 6 depends from Claim 2. Dependent Claim 6 recites that the step of depositing a first layer of Claim 2 includes the steps of: introducing a first vapor of the first material, wherein part of the first vapor condenses on the surface of the first crystal, thereby forming the first layer; and adjusting a thickness of the first layer by varying a temperature of the first crystal (see page 7, lines 4-16 of the specification).

Claim 7 depends from Claim 6. Dependent Claim 7 recites that the first vapor is introduced at a temperature which is less than an optimal growth temperature for epitaxy (see page 7, lines 1-4 of the specification).

Claim 8 depends from Claim 7. Dependent Claim 8 recites that the first crystal comprises group-III/group-V species, and the first material comprises group-V species (see page 6, lines 5-7 and page 7, lines 1-4 of the specification).

Claim 9 depends from Claim 8. Dependent Claim 9 recites that the first crystal comprises GaAs, GaP, InAs or InP, and the first material comprises As₂, As₄, P₂ or P₄ (see page 6, lines 5-7 and page 7, lines 1-4 of the specification).

Claim 10 depends from Claim 9. Dependent Claim 10 recites that the thickness of the first layer ranges from approximately a few Å to approximately a few tens of Å (see page 7, lines 13-15 of the specification).

Claim 11 depends from Claim 10. Dependent Claim 11 recites that the step of introducing a first material includes the step of opening a first shutter blocking a growth chamber from a first vapor source (see page 7, lines 4-6 of the specification).

Claim 12 depends from Claim 6. Dependent Claim 12 recites that the step of depositing a second layer of a second material of Claim 6 includes the steps of: introducing the second vapor, a temperature of the first crystal being maintained at T_d within a range of about 30°C to about 250°C, wherein at least part of the second vapor condenses over the first layer; annealing the second layer by raising the temperature of the first crystal from T_d to a temperature of about 400°C to about 580°C, under a pressure of the first vapor of about 0.008 pa (see page 8, lines 14-18 of the specification).

Claim 13 depends from Claim 12. Dependent Claim 13 recites that an amount of the second vapor introduced is such that the second layer is formed by a mono-layer of atoms of the second material (see page 7, lines 19-20 and page 8, lines 1-5 of the specification).

Claim 14 depends from Claim 13. Dependent Claim 14 recites that the step of introducing the second vapor of Claim 13 comprises the steps of: providing a furnace containing a second vapor of the second material; opening a second shutter allowing the second vapor to travel from the furnace to a growth chamber; wherein the second shutter is opened for a predetermined time duration, whereby to allow a predetermined amount of the second vapor to travel from the furnace to the growth chamber, the predetermined amount of the second vapor being determined by the number of atoms of the second material necessary to form a mono-layer of said atoms over the first layer (see page 8, lines 2-10 of the specification).

Claim 15 depends from Claim 14. Dependent Claim 15 recites that the first crystal comprises group-III/group-V species, the first material comprises group-V species, and the second material comprises group-III species (see page 6, lines 5-7 and page 7, lines 19-20 of the specification).

Claim 16 depends from Claim 15. Dependent Claim 16 recites that the first crystal is selected from the group consisting of GaAs, GaP, InAs and InP, the first material is selected from the group consisting of As₂, As₄, P₂ and P₄, the second material is selected from the group consisting of In, Ga and Al or any combination thereof, and wherein the second vapor has a pressure of about 5×10^{-5} pa, the second vapor has a temperature of about 780°C if the second material is In, the second vapor has a temperature of about 900°C if the second material is Ga, the second vapor has a temperature of about 1200°C if the second material is Al (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 1-10 of the specification).

Claim 17 depends from Claim 16. Dependent Claim 17 recites that for the second material, combinations of Ga, Al, and In, are in a relative ratio substantially equal to the ratio of elements forming the second crystal which is to be epitaxially grown (see page 8, lines 1-5 of the specification).

Claim 18 depends from Claim 16. Dependent Claim 18 recites that the second shutter is opened for a time duration ranging from about 1 second to about 3 seconds (see page 8, lines 1-5 of the specification).

Claim 19 depends from Claim 18. Dependent Claim 19 recites that a number per surface area of group-III atoms forming the mono-layer is about $6.5 \times 10^{14} \text{ cm}^{-2}$ and wherein the second shutter is opened for 2.2 seconds (see page 10, lines 18-20 of the specification).

Claim 20 depends from Claim 16. Dependent Claim 20 recites that the thickness of the first layer ranges from a few Å to a few tens of Å (see page 7, lines 13-14 of the specification).

Claim 21 depends from Claim 12. Dependent Claim 21 recites that the second crystal is a group-III/group-V crystal and wherein the step of epitaxially growing the second crystal of Claim 12 includes the steps of: introducing group-III species into a growth chamber; introducing group-V species into the growth chamber; maintaining a temperature inside the growth chamber near an optimal temperature for epitaxial growth of the second crystal (see page 9, lines 10-15 of the specification).

Claim 22 depends from Claim 21. Dependent Claim 22 recites that the group-V species is introduced by opening a first shutter whereby to let a group-V flux into the growth chamber, and the group-III species is introduced by opening a second shutter whereby to let a group-III flux into the growth chamber (see page 9, lines 10-15 of the specification).

Claim 23 depends from Claim 22. Dependent Claim 23 recites that the ratio of the group-V flux to the group-III flux is substantially in the range of about 1.5 to about 3 (see page 9, lines 10-15 of the specification).

Claim 24 depends from Claim 23. Dependent Claim 24 recites that the second crystal is selected from the group consisting of InAs, $\text{In}_x\text{Ga}_{1-x}\text{As}$, $\text{In}_x\text{Al}_{1-x}\text{As}$ or GaP (see page 9, lines 10-15 of the specification).

Claim 25 depends from Claim 1. Dependent Claim 25 recites that the method is used to manufacture semiconductor devices (see page 12, lines 4-10 of the specification).

Claim 26 depends from Claim 25. Dependent Claim 26 recites that the method is used in microelectronic and optoelectronic applications (see page 1, line 9 of the specification).

Claim 29 depends from Claim 27. Dependent Claim 29 recites that the substrate comprises group-III/group-V species; the crystal comprises group-III/group-V species; the first material comprises group-V species; and the second material comprises group-III species (see page 6, lines 5-7; page 7, lines 1-5; page 7, lines 19-20; and page 8, lines 1-5 of the specification).

Claim 30 depends from Claim 29. Dependent Claim 30 recites that the first layer has a thickness within a range of approximately a few Å to a few tens of Å (see page 7, lines 13-14 of the specification).

Claim 31 depends from Claim 30. Dependent Claim 31 recites that the second layer is a monolayer of group-III atoms (see page 7, lines 19-20 of the specification).

Claim 33 depends from Claim 32. Dependent Claim 33 recites the step d) of epitaxially growing the InAs layer, the step d) including the steps of: introducing a flux of In vapor; introducing a flux As vapor; and maintaining the temperature of the substrate between about 400°C and about 450°C; wherein the ratio of the flux of As vapor to the flux of In vapor is maintained at about 2.5 (see page 11, lines 9-12 of the specification).

Claim 39 depends from Claim 1. Dependent Claim 39 recites that the first crystal comprises the first material of the first layer and the second crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 2-3; and page 9, lines 10-15 of the specification).

Claim 40 depends from Claim 27. Dependent Claim 40 recites that the first crystal comprises the first material of the first layer and the crystal comprises the second material of the second layer; and wherein the first material is a group-V species and the second material is a group-III species (see page 6, lines 5-7; page 7, lines 1-4; page 8, lines 2-3; and page 9, lines 10-15 of the specification).

Claims 2, 3, 4 and 5 as originally filed include the phrase "desorption vapor." These claims were never amended. Due to editorial oversight the word "desorption" was omitted from the phrase "desorption vapor" in our responses to the Examiner's Office Actions. The Applicant respectfully submits that the word "desorption" is included in Claims 2, 3, 4 and 5 since the Examiner's rejections of these claims are based on language as originally filed with the word "desorption."

ISSUES

Issue 1: Whether Claims 1 - 11, 25 - 27, 29 - 31, and 39 - 40 are patentable under 35 U.S.C. 103(a) over Pessa et al., U.S. Patent No. 4,876,218 (hereinafter “Pessa”) in view of Hayakawa et al. U.S. Patent No. 4,824,518 (hereinafter “Hayakawa”)?

Issue 2: Whether Claims 12 - 16 and 18 - 22 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and further in view of Ogasawara U.S. Patent No. 4,897,367 (hereinafter “Ogasawara”)?

Issue 3: Whether Claims 17 and 23 - 24 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and further in view of Grunhaner et al., U.S. Patent No. 5,094,974 (hereinafter “Grunhaner”)?

Issue 4: Whether Claims 32 - 33 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and Grunhaner and further in view of Kubiak et al., U.S. Patent No. 4,330,360 (hereinafter “Kubiak”)?

GROUPING OF CLAIMS

For each ground of rejection which the Applicant contests herein and which applies to more than one claim, such additional claims, to the extent separately identified and argued below, do not stand or fall together.

THE ARGUMENT

Issue 1: Whether Claims 1 - 11, 25 - 27, 29 - 31, and 39 - 40 are patentable under 35 U.S.C. 103(a) over Pessa et al., U.S. Patent No. 4,876,218 (hereinafter “Pessa”) in view of Hayakawa et al. U.S. Patent No. 4,824,518 (hereinafter “Hayakawa”)?

In section 2 of the Office Action of June 23, 2003, the Examiner rejects Claims 1-11, 25-27, 29-31 and 39-40 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa. The Applicant respectfully disagrees with the conclusions that the Examiner has made with regard to the teaching of the cited prior art and submits that Pessa and Hayakawa do not teach, disclose or suggest all of the claim limitations of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on Pessa and Hayakawa, and the rejection of Claims 1-11, 25-27, 29-31 and 39-40 based on Pessa and Hayakawa should be overturned on appeal.

Now the rejection of the specific claims by the Examiner based on the disclosure of Pessa and Hayakawa will be addressed.

Claims 1

Regarding Claim 1, the Examiner asserts, in part, that Pessa: discloses a method of a GaAs film on the surface of a Si or GaAs substrate, where an effusion cell 3 contains a Ga elementary component of a GaAs compound, e.g. Ga atoms, and an effusion cell 4 contains the As elementary component, e.g. as As₄, molecules; teaches heating the substrate to a first growing temperature of 100°C to 500°C, heating the Ga effusion cell

3 to 800°C and heating the As effusion cell 4 to 300°C; teaches opening a shutter 6 in front of the As cell and a vapor beam of As₄ molecules is allowed to act on the surface of the substrate for a period of time which is required for the formation of one atom layer and excess arsenic is removed through re-evaporation and the growing surface by one atom layer only. The Examiner asserts that this reads on the Applicant's first layer of material over the substrate.

The Examiner further asserts, in part, that Pessa: teaches a shutter 6 is closed and a shutter 5 is opened and a vapor beam containing Ga atoms is allowed to act on the growing surface until a number of Ga atoms corresponding to a single atom layer reaches the growing surface. The Examiner asserts that this reads on the Applicant's second layer of second material over the first layer.

The Examiner continues, that the multiple As layers and Ga layers of atoms form a buffer layer (having a thickness of 40 Å to 3000 Å), where the buffer layer causes reduction in lattice strain by creating mismatch dislocations which have a relatively low range of action and which as a result lead to the reduction of threading dislocations. The Examiner asserts that this reads on the Applicant's recite first layer which "substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects" recited by Claim 1.

The Examiner also asserts that Pessa: teaches after the growth of the buffer layer, the substrate is heated to a second growth temperature ranging from 500-700°C and both the Ga and As beams act simultaneously on the growing surface until the desired GaAs film

thickness is obtained by Molecular Beam Epitaxy. The Examiner asserts that this reads on the Applicant's second crystal.

The Applicant respectfully submits that the Examiner failed to fully consider the complete teachings of Pessa. Applicant's invention would not have been obvious to a person having ordinary skill in the art based on the complete teachings of Pessa.

Although the Examiner asserts that Pessa's layers are one atom thick, the Examiner fails to acknowledge that the process of stacking the Ga layer over the As layer continues until the desired GaAs buffer layer thickness is obtained, see column 3, lines 60-64 of Pessa. Pessa teaches that the thickness of the buffer layer may vary within a range from 4 to 300 nm, preferably from 50 to 150 nm, see column 4, lines 5-9. That translates to a minimum and maximum thickness of 40 Å to 3000 Å. Based on these numbers it would require many individual As and Ga one atom layers to create the desired buffer layer.

Additionally, according to Pessa, the buffer layer, grown by Migration Enhanced Epitaxy (MEE), seems to cause reduction in lattice strain by creating mismatch dislocations (type I) which have a relatively low range of action and which as a result lead to the reduction of disadvantageous threading dislocations penetrating deep into the GaAs layer, see column 2, lines 35-40 of Pessa. Type I dislocations are pure edge dislocations, that is the dislocation line runs along the interface and it is only the interfacial region that is degraded, see column 1, lines 39-49 of Pessa. Since interface region gets degraded, it would make sense to make that region as thick as

possible, that is to have a thick buffer layer. Of course, that is exactly what Pessa teaches.

Based on the Pessa, the Examiner expects a person, having ordinary skill in the art, to use only two one atom thick layers of Ga and As (i.e. to use only two layers out of many layers comprising Pessa's thick buffer) when Pessa specifically teaches of pure edge dislocations and a thick buffer layer to accommodate these dislocations. Of course, the Examiner makes this assertion in order to try to make a case that Pessa meets the language of Claim 1 which recites that the second crystal is epitaxially grown over the second layer. However, it is not clear what would prompt a person, having ordinary skill in the art, to use only a two atom thick buffer layer (one layer of Ga atoms and one layer of As atoms) knowing that MEE creates mismatch dislocations that would significantly degrade such a two atom thick buffer layer.

It is submitted that a person skilled in the art would not modify Pessa or assume that the first two one atom thick layers would be satisfactory in view of Pessa teaching that many such layers are needed to accommodate the dislocations.

This is a simple case of the Examiner using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art.

Moreover, Applicant's Claim 1 recites "wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and

formation of dislocation defects." Based on the Examiner's rejections it is also not clear what would prompt a person, having ordinary skill in the art, to believe that a single atom layer in a degraded two atom thick buffer layer, supposedly disclosed in Pessa, would substantially accommodate strain accumulated between the first crystal and the second crystal. Of course a person of ordinary skill would not believe it since Pessa tells us that it does not happen.

Since Pessa teaches the use of many Ga and As one atom thick layers to obtain reduction in lattice strain. It is submitted that a person of ordinary skill in the art would draw from this that the strain relief is distributed over all of the layers. The Examiner's belief that the first one atom layer in Pessa substantially accommodates strain would seem to imply that the remaining layers accommodate essentially no strain. The Applicant believes that the Examiner's position is unorthodox and flies in the face of conventional notions of physics, in particular:

- 1) the strain relief is believed to occur uniformly if the thickness is greater than the so-called "Matthews Blakeslee critical thickness"; and
- 2) if the thickness is under the Matthews-Blakeslee critical thickness, then strain relief occurs with dislocations.

The Examiner failed to provide any evidence to support his beliefs, which the applicant believes are unorthodox, even when the applicant called upon the Examiner to cite some reference supporting his views. The Examiner also failed to comply with the rules of practice, particularly 37 C.F.R. 1.104(d)(2) and supply the Affidavit specifically setting forth the facts upon which he relies in rejecting Claim 1.

Further, Pessa's patent teaches away from the Applicant's invention. As the Examiner stated, the Pessa patent describes a buffer layer that "causes reduction in lattice strain by **creating mismatch dislocations**," see column 2, lines 35-40 in Pessa and see page 3, lines 1-3 of Office Action dated June 23, 2003. The Applicant submits that the current invention prevents strain relaxation and formation of dislocation defects thereby preventing mismatch dislocations.

An obstacle in realizing next-generation microelectronic and optoelectronic devices and optimal integration of these devices is found in lattice mismatches between different crystals of group III-V semiconductor materials. Generally, the lattice mismatches between a substrate and an epitaxial over-layer induce strains within the over-layer. This may lead to strain relaxation which can result in formation of material defects such as dislocations within the crystalline structure of the over-layer. The Applicant's Figure 1 illustrates a mismatched over-layer 1 epitaxially grown over a substrate 2, the boundary between the over-layer 1 and the substrate 2 being indicated with reference numeral 4. As shown in Figure 1, the lattice associated with over-layer 1 is different from the lattice constant associated with the substrate 2, hence the term "mismatched over-layer." Strain relaxation due to lattice mismatch is accommodated by the formation of mismatch dislocations 3 within the crystal. Defects within a crystal generally degrade the performance of devices made from the crystal. It is thus useful to provide means for growing a crystal over-layer which has a different lattice constant from the substrate on which the over-layer is grown, in such a fashion that strain relaxation does not occur and **mismatch dislocations do not form**. Applicant's Figure 2 is an example of a schematic representation of how lattice mismatch is taken by a condensed layer of group-V species, in which the structure of over-layer 1 is preserved and **no mismatch dislocations are formed**. Please refer to page 1, lines 9-21 and page 2, lines 1-4 of the

disclosure. The present invention answers the need for a method of growing a crystal over a substrate such that mismatch dislocations are substantially prevented from appearing within the crystal, even though the crystal and the substrate have different lattice constants, by suppressing strain relaxations associated with lattice-mismatches and preventing formation of dislocation defects, refer to page 3, lines 1-20 of the applicant's application.

Further regarding Claim 1, the Examiner asserts, in part, that Hayakawa teaches a GaAs substrate is heated to about 600°C during a radiation treatment by an As₄ molecular beam with about 10⁻⁶ to 10⁻⁵ torr and is allowed to stand at about 600°C for about 10 minutes, and after which the temperature of the GaAs substrate is lowered to 200°C or less during a radiation treatment by the As₄ molecular beam, thereby achieving complete removal of an oxidized film formed on the GaAs substrate and obtaining a GaAs substrate with a clean surface. The Examiner asserts that this reads on the Applicant's cleansing by thermal desorption and it would have been obvious to a person of ordinary skill in the art at the time of the invention to modify Pessa with Hayakawa to clean the surface of the substrate to remove oxide from the surface.

The Applicant respectfully submits that the Examiner failed to fully consider that Pessa teaches away from Hayakawa, therefore, the Applicant's invention would not have been obvious to a person having ordinary skill in the art based on combined teachings of Pessa and Hayakawa.

According to Hayakawa "the deposited As is completely evaporated by a heating process prior to the subsequent epitaxial growth process," see column 4, lines 60-62 of Hayakawa. Hayakawa goes on to teach that "in order to grow high-quality crystals on

the substrate, the growth temperature is controlled as follows: The growth is started at a relatively low temperature in order to prevent as much deterioration of the GaAs substrate as possible resulting from the removal of As therefrom," see column 5, lines 11-16 of Hayakawa. Unlike Hayakawa, Pessa teaches that "the shutter 6 is opened in front of the As cell and the vapor beam (As_4 molecules) is allowed to act on the surface of the substrate 1 for a period of time which is required for the formation of one atom layer," see column 3, lines 40-44 of Pessa. It is unclear how the Examiner expects an ordinary person skilled in the art to combine Pessa and Hayakawa when Hayakawa teaches the complete removal of As while Pessa teaches the formation of multiple one atom thick As layers.

To summarize, based on Pessa's patent and Hayakawa's patent the Examiner failed to show how it would have been obvious to a person having ordinary skill in the art to conceive

"a method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the step of: cleansing a surface of the first crystal by thermal desorption; depositing a first layer of a first material over the surface of the first crystal; depositing a second layer of a second material over the first layer; and epitaxially growing the second crystal over the second layer; wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects"

as claimed in Claim 1, for the following reasons:

(1) The Examiner assumes that it would be obvious to use only two layers in Pessa however that is illogical since Pessa teaches not only the use of multiple layers, but also why multiple layers are needed.

(2) The Examiner assumes that a person having ordinary skill in the art would use only two of the multiple one atom thick layers of Ga and As, taught by Pessa, even though Pessa teaches of pure edge dislocations and a thick buffer layer to accommodate these dislocations.

(3) The Examiner mistakenly assumes that a single layer of the multiple one atom thick layers discussed in Pessa, is enough to "substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth," as claimed in Claim 1.

(4) Pessa patent teaches away from the Applicant's invention. Pessa specifically describes a buffer layer that causes reduction in lattice by creating mismatch dislocations. Where as Claim 1 states "first layer substantially accommodates strain accumulated between the first crystal and the second crystal during the epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects."

(5) The Examiner wrongfully combined the above references because Hayakawa patent teaches away from Pessa patent. Hayakawa teaches complete removal of As layer where as Pessa teaches the formation of multiple one atom thick As layers.

Therefore, the Applicant believes the Claim 1 is patentable over the cited references.

Claims 2-3

Regarding Claims 2-3, the Applicant submits that Claims 2-3 are patentable over Pessa and Hayakawa based upon their dependence on Claim 1. Further, the Applicant submits that the Examiner has not shown that Pessa and Hayakawa teach, discloses, or suggests "the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa" as recited in Claim 3. According to Hayakawa's preferred embodiment "GaAs substrate is

gradually heated to about 600°C during a radiation treatment by an As₄ molecular beam with about 10⁻⁶-10⁻⁵ torr," see column 4, lines 46-49 of Hayakawa. Pressure of 10⁻⁶-10⁻⁵ torr is roughly equivalent to 0.00013 - 0.0013 pa. The range of pressure taught by Hayakawa is much lower than the pressure range taught in Claim 3. The maximum pressure in Hayakawa (.0013 pa) is three times lower than the minimum pressure in Claim 3 (.004 pa).

The Examiner asserts that Hayakawa teaches As molecular beam pressure of 10⁻⁴-10⁻⁵ torr (0.013 to 0.0013 pa). The Applicant submits that Hayakawa teaches away from the use of As molecular beam pressure of 10⁻⁴-10⁻⁵ torr by using pressure of 10⁻⁶-10⁻⁵ torr in his preferred embodiment. In describing the background of the invention Hayakawa states that "during the process of removal of the oxidized film of GaAs, it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10⁻⁴-10⁻⁵ torr in a short time. Thus, it takes a long time for the removal of the oxidized film," see column 1, line 65 to column 2, line 2 of Hayakawa. The Applicant submits that Hayakawa used As molecular beam pressure of 10⁻⁶-10⁻⁵ torr in his preferred embodiment to lower the strength of the As molecular beam and to shorten the time for the removal of the oxidized film.

Therefore, the Applicant believes the Claims 2-3 are patentable over the cited references.

Claims 4-5 and 8-9

Regarding Claims 4-5 and 8-9, the Examiner asserts that Hayakawa in combination with Pessa teaches a GaAs substrate and an As₄ vapor. Although cited art teaches a GaAs

substrate and an As₄ vapor, it does not teach a GaP or InP crystal with InAs, P₂ or P₄ vapor as claimed in Claim 5.

Further, Claims 4-5 and 8-9 directly or indirectly depend from Claim 1, they are believed to be patentable over the cited references.

Further, Claims 4-5 directly or indirectly depend from Claim 3, they are believed to be patentable over the cited references.

Claim 6

Regarding Claim 6, the Applicant submits that Claim 6 is patentable over Pessa and Hayakawa at least based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has not shown that Pessa and Hayakawa teach, discloses, or suggests “adjusting a thickness of the first layer by varying a temperature of the first crystal” as recited in Claim 6. The Examiner asserts that Hayakawa in combination with Pessa teaches removing excess arsenic by re-evaporation, so the growing surface grows by only one atom layer at a time, and this reads on adjusting the thickness by varying a temperature of the first crystal. Once again the Examiner is not quoting the exact and complete language of the Pessa patent, thereby changing the meaning of what Pessa is trying to teach. Accordingly, Pessa teaches removing excess arsenic through re-evaporation, and the growing surface grows by one atom layer only. After this time period (of the order of 1 sec), the shutter 6 is closed and the shutter 5 is opened, see column 3, lines 45-49. This seems to mean that shutter 6 is opened for a specified time period until the arsenic is removed through re-evaporation and the surface grows by one atom layer only. Unlike in Claim 6, Pessa does not teach changing the temperature to

adjust the thickness of the first layer. On the contrary, the time period of how long the shutter 6 is open is used to adjust the thickness of the layer. Further, Pessa does not teach how to adjust the thickness if the layer is more than one atom thick. On the contrary, according to Pessa "the growing surface grows by one atom layer only," see column 3, lines 47-48 of Pesa. In the specification the Applicant specifically teaches that the As₂ condensed layer can be thinned down to the desired thickness by raising the temperature of the substrate to about 250°C, see page 10, lines 10-12.

Therefore, the Applicant believes the Claim 6 is patentable over the cited references.

Claim 7

Regarding Claim 7, the Applicant submits that Claim 7 is patentable over Pessa and Hayakawa based upon its dependence on Claims 1 and 6.

Claim 10 and 30

Regarding Claims 10 and 30, the Applicant submits that Claim 10 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1. The Applicant submits that Claim 30 is patentable over Pessa and Hayakawa based upon its dependence on Claim 27.

Claim 11

Regarding Claim 11, the Applicant submits that Claim 11 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1.

Claims 25-26

Regarding Claims 25-26, the Applicant submits that Claims 25-26 are patentable over Pessa and Hayakawa based upon their dependence on Claim 1.

Claim 27

Regarding Claim 27, the same argument applies as for Claim 1. Therefore, the Applicant believes that Claim 27 is patentable over the cited references.

Claim 29 and 39-40

Regarding Claims 29 and 40, the Applicant submits that Claims 29 and 40 are patentable over Pessa and Hayakawa based upon their dependence on Claim 27. Regarding Claim 39, the Applicant submits that Claim 39 is patentable over Pessa and Hayakawa based upon its dependence on Claim 1.

Claim 31

Regarding Claim 31, the Applicant submits that Claim 31 is patentable over Pessa and Hayakawa based upon its dependence on Claim 27.

Issue 2: Whether Claims 12 - 16 and 18 - 22 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and further in view of Ogasawara U.S. Patent No. 4,897,367 (hereinafter “Ogasawara”)?

In section 3 of the Office Action of June 23, 2003, the Examiner rejects Claims 12-16 and 18-22 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa as applied to Claims 1-11, and further in view of Ogasawara. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Ogasawara teaches a process of growing Gallium Arsenide (GaAs) on a Silicon Substrate (Si). Silicon belongs to group-IV species unlike the group III-V species substrate claimed in the present application. As a person of ordinary skill in the art knows group-IV species have different characteristics and properties from group III-V species, therefore, it is not clear what a person familiar with Pessa and Hayakawa would gain from Ogasawara. A person of ordinary skill in the art would not look to group-IV species art when trying to improve group III-V crystal growth. It is the Applicant's belief that the only reason Ogasawara was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Ogasawara is non-analogous art and a person trying to improve group III-V crystal growth would not look to it. Also, the Examiner utterly failed to show any motivation for a person skilled in the art to combine these references. Thus claims 12-16 and 18-22 are patentable over the cited references.

Claim 12

Regarding Claim 12, the Applicant submits that Claim 12 is patentable over Pessa, Hayakawa and Ogasawara, at least based upon its dependence on Claim 1 and Claim 6. Moreover, in addition to Pessa being incompatible with Hayakawa, Applicant does not understand what the motivation is (or the effect of) combining these two disclosures with Hayakawa. Furthermore, the Applicant submits that the Examiner has not shown that Pessa, Hayakawa and Ogasawara teach, disclose, or suggest “annealing the second layer ... under a pressure of the first vapor of about 0.008 pa” as recited in Claim 12. Pessa teaches that first layer As is deposited on the substrate by opening shutter 6, then shutter 6 is closed and a second layer Ga is deposited by opening shutter 5, then again shutter 5 is closed and a third layer As is deposited by opening shutter 6, and so on until the desired buffer layer is completed, see column 3, lines 31-65. As the Examiner admits Pessa and Hayakawa do not teach annealing the second layer by raising the temperature of the first crystal under a pressure of the first vapor of about 0.008 pa, see page 6 lines 1-2 of the Office action dated June 23, 2003. Similarly, Ogasawara does not provide at what pressure the As is to be released onto the substrate, see column 2, lines 55-68. Therefore, it would not have been obvious to a person having ordinary skill in the art to combine Pessa, Hayakawa and Ogasawara or keep the pressure of the first vapor at 0.008 pa. The Applicant submits that Claim 12 is patentable over the cited art.

This is another example of the Examiner using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art. Further, the Examiner failed to show motivation to combine these references in the matter set forth in his Office Actions. The Examiner is using

hindsight to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task for one skilled in the art.

Claim 13

Regarding Claim 13, the Applicant submits that Claim 13 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 12. The Applicant submits that Claim 13 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that Ogasawara teaches introducing a Ga flux to form a Ga monolayer. The Applicant submits that the Examiner is mistaken. According to Ogasawara "a Ga beam is irradiated onto the substrate 1 in an amount needed to form a GaAs layer and thus the first GaAs layer is formed," see column 2, lines 43-45 of Ogasawara. Contrary to the Examiner, Ogasawara does not teach, disclose or suggest the formation of Ga monolayer. Ogasawara teaches the formation of first GaAs layer followed by Si layer, see Figure 1 of Ogasawara.

Once again the Examiner is using the claim as a road map to interpret a prior art document as opposed to considering what the document really teaches to a person skilled in the art. The Examiner is using hindsight to combine a large number of references in a complex matter to arrive allegedly at the claimed invention. The combination proposed by the Examiner is not logical for the reasons stated and there is certainly no motivation for making the suggested combination.

Claim 14

Regarding Claims 14, the Applicant submits that Claim 14 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 15

Regarding Claims 15, the Applicant submits that Claim 15 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that the combination of Pessa, Hayakawa and Ogasawara teaches a GaAs first crystal, an As first material and a Ga second material. The Examiner is using hindsight to try to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task, if not an impossible task, for one skilled in the art. As stated above Ogasawara teaches a process for growing GaAs on Si substrate, contrary to the Examiner's assertion that it teaches a GaAs first crystal.

Additionally, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 16

Regarding Claims 16, the Applicant submits that Claim 16 is patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Examiner asserts that the combination of Pessa, Hayakawa and Ogasawara teaches a GaAs first crystal, a first material of As₄ and a second material Ga. The Examiner is using hindsight to combine a large number of references in a complex matter to arrive at the claimed invention which otherwise would be an onerous task for one skilled in the art. As stated above Ogasawara teaches a process for growing GaAs on Si substrate, contrary to the Examiner's assertion that it teaches a GaAs first crystal.

Also, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claims 18-22

Regarding Claims 18-16, the Applicant submits that Claims 18-16 are patentable over Pessa, Hayakawa and Ogasawara based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Issue 3: Whether Claims 17 and 23 - 24 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and further in view of Grunthaner et al., U.S. Patent No. 5,094,974 (hereinafter "Grunthaner")?

In section 4 of the Office Action of June 23, 2003, the Examiner rejects Claims 17 and 23-24 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa and Ogasawara as applied to Claims 12-16 and 21-22, and further in view of Grunthaner. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Grunthaner teaches growth of III-V films by control of MBE growth front stoichiometry. Unlike Pessa, Grunthaner "grow[s] an extensive GaAs buffer layer of 1 to 2 micrometers thickness," see column 4, lines 42-44 of Grunthaner. That translates to a minimum and maximum thickness of 10,000 Å to 20,000 Å, well above the thickness of two atom thick buffer layer the Examiner alleges is taught by Pessa. How does the Examiner justify combining these two references? In rejecting Claim 1 above the Examiner used Pessa to allege that the two, of many, one atom thick layers taught in Pessa read on Claim 1. Now the Examiner combines Pessa with

Grunthaner. The Examiner should not consider a thin buffer layer when rejecting Claim 1 and a thick buffer layer when rejecting Claims 17 and 23-24 that are dependent on Claim 1. The Examiner used Applicant's claims as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. It is the Applicant's belief that the only reason Grunthaner was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Grunthaner is non-analogous art and the Examiner utterly failed to show any motivation for a person skilled in the art to combine Pessa with Grunthaner. Thus Claims 17 and 23-24 are patentable over the cited references.

Claims 23-24

Regarding Claims 23-24, the Applicant submits that Claims 23-24 are patentable over Pessa, Hayakawa Ogasawara and Grunthaner based upon its dependence on Claim 1. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Moreover, according to the Examiner Pessa, Hayakawa and Ogasawara fail to teach the ratio of the group V flux to the group III flux is substantially in the range of about 1.5 to about 3. The Examiner asserts that in a method of growing group III-V film by control of MBE growth stoichiometry, Grunthaner teaches instantaneous flux ratios of In to As have been critical to the control of defect generation in the lattice mismatched epitaxy of InAs on GaAs. The Examiner further asserts that it would have been obvious to a person of ordinary skill in the art to modify

the combination Pessa, Hayakawa and Ogasawara with Grunthaner by optimizing the ratio of group V flux to the group-III flux substantially in the range of 1.5 to about 3 by conducting routine experimentation. The Applicant respectfully disagrees with the Examiner's assertions. Although Grunthaner recognizes that "flux ratios of In to As have been critical to the control of defect generation in the lattice mismatched epitaxy of InAs on GaAs substrates," see column 2, lines 30-33, the Applicant submits that Grunthaner's approach to determining the flux ration would not have yield the range of 1.5 to about 3 through routine experimentation. According to Grunthaner, "by introducing small delay times in the relative opening sequence of shutter operation program, ... [Grunthaner] could control the effective In to As ratio throughout the monolayer growth cycle," see column 2, lines 43-47. By varying "the appropriate delays between In, As and Ga shutters ... [Grunthaner] found a strong variation in the converge or quality of the InAs film," see column 3, lines 3-5. Basically Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike Claim 23, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Claim 17

Regarding Claim 17, the Applicant submits that Claim 17 is patentable over Pessa, Hayakawa Ogasawara and Grunthaner based upon its dependence on Claim 1 and Claim 16. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has

not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Moreover, the Examiner asserts that the selection of reaction parameters such as temperature and concentration is obvious and the ration of fluxes is a result effective variable as taught by Grunthaner. As discussed above with reference to Claims 23 and 24, Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike present application, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Issue 4: Whether Claims 32 - 33 are patentable under 35 U.S.C. 103(a) over Pessa in view of Hayakawa and Ogasawara and Grunthaner and further in view of Kubiak et al., U.S. Patent No. 4,330,360 (hereinafter “Kubiak”)?

In section 5 of the Office Action of June 23, 2003, the Examiner rejects Claims 32-33 under 35 U.S.C. 103(a) as being made obvious by Pessa in view of Hayakawa, Ogasawara and Grunthaner as applied to Claims 17 and 23, and further in view of Kubiak. To establish a *prima facie* case of obviousness, the Examiner must show: (1) that there is some suggestion or motivation to modify the reference or to combine reference teachings; (2) that there is a reasonable expectation of success; and (3) that the prior art reference or references teach or suggest each and every claim limitation. See MPEP 2142. Further, the suggestion or motivation to modify or combine and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. The Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner

shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Applicant submits that the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claims are patentable over these cited references.

Kubiak teaches molecular beam deposition technique using gaseous sources of group V elements. Kubiak's discloses "a method and apparatus for growing ... group III-V semiconductor layers on a semiconductor body ... by molecular beam deposition. The group III-V semiconductor layer is formed by directing a group III molecular beam and a group V molecular beam at a semiconductor body," see column 2, lines 10-17. Unlike Pessa, Kubiak does not teach the use of a thick buffer layer between the group III-V semiconductor layers and a semiconductor body. Once again, how does the Examiner justify combining these two references? In rejecting Claim 1 above the Examiner used Pessa to allege that the two, of many, one atom thick layers taught in Pessa read on Claim 1. Now the Examiner combines Pessa with Kubiak. The Examiner should not consider a buffer layer when rejecting Claim 1 and no buffer layer when rejecting Claims 32-33. The Examiner used Applicant's claims as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. It is the Applicant's belief that the only reason Kubiak was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Kubiak is non-analogous art and the Examiner utterly failed to show any motivation for a person skilled in the art to combine Pessa with Kubiak.

The Examiner is using hindsight to combine a large number of references in a complex matter to arrive allegedly at the claimed invention. The combination proposed by the Examiner is not logical from the reasons stated and there is certainly no motivation for

making the suggested combination. Thus Claims 32-33 are patentable over the cited references.

Claim 32

Regarding Claim 32, the Examiner asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach all of the limitations of Claim 32 including heating a substrate to 600°C and annealing under a pressure of As₄ vapor, which is equivalent to As₂ of 10⁻⁴ to 10⁻⁵ torr (0.013 to 0.0013 pa). The Applicant strongly disagrees with the Examiner's assertion. Once again the Examiner is improperly quoting prior art. Although Hayakawa teaches applying As₄ to the substrate the actual pressure range is 10⁻⁵ to 10⁻⁶ torr (0.0013 to 0.00013 pa), the pressure disclosed in Claim 32 is 0.008 pa. which is not in the range specified by Hayakawa.

The Examiner further asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach growing one arsenic atom layer and removing excess arsenic through re-evaporation, where the evaporation temperature of As is on the order of 300°C. Unfortunately, the Examiner is once again not paying close attention to what is taught in the prior art. Accordingly, Pessa teaches removing excess arsenic through re-evaporation, and the growing surface grows by one atom layer only. After this time period (of the order of 1 sec), the shutter 6 is closed and the shutter 5 is opened, see column 3, lines 45-49. This seems to mean that shutter 6 is opened for a specified time period until the arsenic is removed through re-evaporation and the surface grows by one atom layer only. Unlike in Claim 6, Pessa does not teach changing the temperature to adjust the thickness of the first layer. Further, Pessa does not teach how to adjust the thickness if the layer is more than one atom thick. On the contrary, according to Pessa "the growing surface grows by

one atom layer only," see column 3, lines 47-48 of Pessa. In Claim 32 the Applicant specifically teaches "adjusting the thickness of the condensed layer of As_2 by raising the temperature of the substrate to about 250°C , thereby thinning the condensed layer of As_2 to several tens of Å."

The Examiner goes on to assert that Pessa, Hayakawa, Ogasawara, and Grunthaner teach that it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10^{-4} to 10^{-5} torr in a short time, therefore As used in the growth chamber is present during growth of compound semiconductors, and this reads on the Applicant's subjecting the substrate to an As_2 vapor pressure of about 0.008 pa for forming a monolayer of In atoms. As stated above, the Applicant submits that Hayakawa teaches away from the use of As molecular beam pressure of 10^{-4} - 10^{-5} torr by using pressure of 10^{-6} - 10^{-5} torr in his preferred embodiment. In describing the background of the invention Hayakawa states that "during the process of removal of the oxidized film of GaAs, it is impossible to lower the strength of the As molecular beam which has an extremely high pressure of 10^{-4} - 10^{-5} torr in a short time. Thus, it takes a long time for the removal of the oxidized film," see column 1, line 65 to column 2, line 2 of Hayakawa. The Applicant submits that Hayakawa used As molecular beam pressure of 10^{-6} - 10^{-5} torr in his preferred embodiment to lower the strength of As molecular beam and to shorten the time for the removal of the oxidized film.

Since Hayakawa teaches that As_2 molecular beam is 10^{-5} to 10^{-6} torr (0.0013 to 0.00013 pa), column 4, lines 45-50, it is nowhere near 0.008 pa recited in Claim 32. Also, Hayakawa teaches that the substrate is exposed to As_4 for removal of the oxidized film in the pre-treatment chamber 3. Upon completion of removal of the oxidized film the substrate is carried to the growth chamber 4, see column 3, lines 45-60 and column 4,

lines 3-5. Contrary to the Examiner's assertion none of the prior art teaches "introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As₂ vapor pressure of about 0.008 pa; and raising the temperature of the substrate to about 400°C while the As₂ vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer."

The Examiner further asserts that Pessa, Hayakawa, Ogasawara, and Grunthaner teach that the buffer layer reduces dislocations between the substrate and the epitaxial layer, and it reads on the Applicant's epitaxial growth does not introduce dislocation defects caused by lattice mismatch. As discussed above for Claim 1, Applicant's invention teaches away from the Pessa patent. As the Examiner stated the Pessa patent describes a buffer layer that "causes reduction in lattice strain by **creating mismatch dislocations**," see column 2, lines 35-40 in Pessa and see page 3, lines 1-3 of Office Action dated June 23, 2003. The Applicant submits that the current invention prevents strain relaxation and formation of dislocation defects thereby preventing mismatch dislocations.

The Examiner also asserts that the combination of Pessa, Hayakawa, Ogasawara, and Grunthaner is silent to introducing In vapor at a temperature of about 790°C. According to the Examiner, Kubiak teaches nominal effusion cell temperature s range from 900°C-1000°C for Ga and 800°C-840°C for In. The Examiner asserts that it would have been obvious to a person of ordinary skill in the art to modify the combination of Pessa, Hayakawa, Ogasawara, and Grunthaner with Kubiak by optimizing the effusion cell temperature by conducting routine experimentation of result effective variables. It seems like the Examiner used Claim 32 as a road map to perform an exhaustive search of prior art documents as opposed to considering what the document really teaches to a person skilled in the art. As stated above, Kubiak does not teach the use of two

layers between the group III-V semiconductor layers and a semiconductor body. A person of ordinary skill in the art would not look to the art teaching depositing group III-V semiconductor layers directly on a semiconductor body when trying to improve crystal growth with two layers between the crystals. It is the Applicant's belief that the only reason Kubiak was cited was because the Examiner has performed an *ex post facto* analysis of the Applicant's claims. Kubiak is non-analogous art and a person trying to improve crystal growth with two layers between the crystals would not look to it. Also, the Examiner utterly failed to show any motivation for a person skilled in the art to combine these references.

The Examiner failed to demonstrate that by reading cited prior art it would have been obvious to a person having ordinary skill in the art to come up with

"A method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of: a) extracting surface oxides from a surface of the substrate by thermal desorption, the thermal desorption including the steps of: a1) heating the substrate to a temperature of about 600°C; and a2) annealing the substrate for about 10 minutes under a pressure of As₂ vapor of about 0.008 pa; b) depositing a condensed layer of As₂ on the surface of the substrate, depositing a condensed layer including the steps of b1) lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As₂ vapor pressure of about 0.008 pa, whereby a condensed layer of As₂ is formed on the surface of the substrate; and b2) adjusting the thickness of the condensed layer of As₂ by raising the temperature of the substrate to about 250°C, thereby thinning the condensed layer of As₂ to several tens of Å; and c) depositing a mono-layer of In atoms over the condensed layer of As₂ the depositing a mono-layer comprising the steps of c1) introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As₂ vapor pressure of about 0.008 pa; and c2) raising the temperature of the substrate to about 400°C while the As₂ vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer; wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not

introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer"

as claimed in Claim 32. Therefore, the Applicant believes the Claim 32 is patentable over the cited references.

Claim 33

Regarding Claim 33, the Applicant submits that Claim 33 is patentable over Pessa, Hayakawa Ogasawara, Grunthaner and Kubiak based upon its dependence on Claim 32. Further, the Applicant submits that the Examiner has neither adequately shown a motivation to combine the references in the manner done by the Examiner nor has the Examiner shown that the asserted combination teaches each and every element of the rejected claims. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Additionally, the Examiner agrees that the combination of Pessa, Hayakawa Ogasawara, Grunthaner and Kubiak does not teach a ratio of flux is maintained at 2.5. According to the Examiner, the selection of reaction parameters such as temperature and concentration is obvious. The Applicant strongly disagrees with the Examiner's assertions. As discussed above, Grunthaner controls the flux ratio by timing the opening and closing of shutters that release In and As compounds on to the substrate, see column 2, lines 11-65 and Figure 2 of Grunthaner. Unlike present application, Grunthaner does not disclose, teach or suggest any numerical flux ratios. Therefore, the Examiner has not established a *prima facie* case of obviousness based on the cited prior art, and the claim is patentable over these cited references.

Conclusion

For the extensive reasons advanced above, Appellant respectfully contends that each claim is patentable. Therefore, reversal of all rejections and objections is courteously solicited.

The Commissioner is authorized to charge any additional fees which may be required or credit overpayment to deposit account no. 12-0415. In particular, if this Appeal Brief is not timely filed, the Commissioner is authorized to treat this response as including a petition to extend the time period pursuant to 37 CFR 1.136(a) requesting an extension of time of the number of months necessary to make this response timely filed and the petition fee due in connection therewith may be charged to deposit account no. 12-0415.

I hereby certify that this correspondence is being deposited with the United States Post Office with sufficient postage as express mail in an envelope addressed to: Mail Stop Appeal Brief - Patents, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22323-1450 on

December 22, 2003

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1. A method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the steps of:

- a) cleansing a surface of the first crystal by thermal desorption;
- b) depositing a first layer of a first material over the surface of the first crystal;
- c) depositing a second layer of a second material over the first layer; and
- d) epitaxially growing the second crystal over the second layer;

wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects.

2. The method of claim 1, wherein the step a) of cleansing the surface of the first crystal by thermal desorption includes the steps of:

- a1) bringing a temperature of the first crystal to T_s °C, T_s ranging from about 495°C to about 600°C;
- a2) introducing a desorption vapor having a desorption vapor pressure; and
- a3) annealing the first crystal under the desorption vapor pressure at temperature T_s ;

wherein the desorption vapor pressure is greater than a vapor pressure of the first crystal at temperature T_s .

3. The method of claim 2, wherein the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa, and wherein surface oxides of the first crystal are desorbed.

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4. The method of claim 3, wherein the first crystal comprises group-III/group-V species, and the desorption vapor comprises group-V species.
 5. The method of claim 4, wherein the first crystal comprises GaAs, GaP, InAs or InP, and wherein the desorption vapor comprises As₂ or As₄ if the first crystal is GaAs or InAs, or the desorption vapor comprises InAs, P₂ or P₄ if the first crystal is GaP or InP.
 6. The method of claim 2, wherein the step b) of depositing a first layer includes the steps of:
 - b1) introducing a first vapor of the first material, wherein part of the first vapor condenses on the surface of the first crystal, thereby forming the first layer; and
 - b2) adjusting a thickness of the first layer by varying a temperature of the first crystal.
 7. The method of claim 6, wherein the first vapor is introduced at a temperature which is less than an optimal growth temperature for epitaxy.
 8. The method of claim 7, wherein the first crystal comprises group-III/group-V species, and the first material comprises group-V species.
 9. The method of claim 8, wherein the first crystal comprises GaAs, GaP, InAs or InP, and the first material comprises As₂, As₄, P₂ or P₄.
 10. The method of claim 9, wherein the thickness of the first layer ranges from approximately a few Å to approximately a few tens of Å.

11. The method of claim 10, wherein the step b1) of introducing a first vapor of the first material, includes the step of opening a first shutter blocking a growth chamber from a first vapor source.

12. The method of claim 6, wherein the step c) of depositing a second layer of a second material includes the steps of:

c1) introducing the second vapor, a temperature of the first crystal being maintained at T_d within a range of about 30°C to about 250°C , wherein at least part of the second vapor condenses over the first layer;

c2) annealing the second layer by raising the temperature of the first crystal from T_d to a temperature of about 400°C to about 580°C , under a pressure of the first vapor of about 0.008 pa.

13. The method of claim 12, wherein an amount of the second vapor introduced is such that the second layer is formed by a mono-layer of atoms of the second material.

14. The method of claim 13, wherein the step c1) of introducing the second vapor comprises the steps of:

c11) providing a furnace containing a second vapor of the second material;

c12) opening a second shutter allowing the second vapor to travel from the furnace to a growth chamber;

wherein the second shutter is opened for a predetermined time duration, whereby to allow a predetermined amount of the second vapor to travel from the furnace to the growth chamber, the predetermined amount of the second vapor being determined by the number of atoms of the second material necessary to form a mono-layer of said atoms over the first layer.

15. The method of claim 14, wherein the first crystal comprises group-III/group-V species, the first material comprises group-V species, and the second material comprises group-III species.

16. The method of claim 15, wherein the first crystal is selected from the group consisting of GaAs, GaP, InAs and InP, the first material is selected from the group consisting of As₂, As₄, P₂ and P₄, the second material is selected from the group consisting of In, Ga and Al or any combination thereof, and wherein the second vapor has a pressure of about 5×10^{-5} pa, the second vapor has a temperature of about 780°C if the second material is In, the second vapor has a temperature of about 900°C if the second material is Ga, the second vapor has a temperature of about 1200°C if the second material is Al.

17. The method of claim 16, wherein for the second material, combinations of Ga, Al, and In, are in a relative ratio substantially equal to the ratio of elements forming the second crystal which is to be epitaxially grown.

18. The method of claim 16, wherein the second shutter is opened for a time duration ranging from about 1 second to about 3 seconds.

19. The method of claim 18, wherein a number per surface area of group-III atoms forming the mono-layer is about $6.5 \times 10^{14} \text{ cm}^{-2}$ and wherein the second shutter is opened for 2.2 seconds.

20. The method of claim 16, wherein the thickness of the first layer ranges from a few Å to a few tens of Å.

21. The method of claim 12, wherein the second crystal is a group-III/group-V crystal and wherein the step d) of epitaxially growing the second crystal includes the steps of:

- d1) introducing group-III species into a growth chamber;
- d2) introducing group-V species into the growth chamber;
- d3) maintaining a temperature inside the growth chamber near an optimal temperature for epitaxial growth of the second crystal.

22. The method of claim 21, wherein the group-V species is introduced by opening a first shutter whereby to let a group-V flux into the growth chamber, and the group-III species is introduced by opening a second shutter whereby to let a group- III flux into the growth chamber.

23. The method of claim 22, wherein the ratio of the group-V flux to the group-III flux is substantially in the range of about 1.5 to about 3.

24. The method of claim 23, wherein the second crystal is selected from the group consisting of InAs, $\text{In}_x\text{Ga}_{1-x}\text{As}$, $\text{In}_x\text{Al}_{1-x}\text{As}$ or GaP.

25. The method of claim 1, wherein the method is used to manufacture semiconductor devices.

26. The method of claim 25, wherein the method is used in microelectronic and optoelectronic applications.

27. A method of preparing a substrate for subsequent epitaxial growth of a crystal over the substrate, the method comprising the steps of:

- a) cleansing a surface of the substrate by thermal desorption;

b) depositing a first layer of a first material over the surface of the substrate; and
c) depositing a second layer of a second material over the first layer, wherein the crystal is deposited over the second layer, wherein the first layer accommodates strain accumulated between the substrate and the crystal during epitaxial growth, thereby preventing strain relaxation and formation of dislocation defects.

28. (Cancelled)

29. The method of claim 27 wherein:

the substrate comprises group-III/group-V species;
the crystal comprises group-III/group-V species;
the first material comprises group-V species; and
the second material comprises group-III species.

30. The method of claim 29, wherein the first layer has a thickness within a range of approximately a few Å to a few tens of Å.

31. The method of claim 30, wherein the second layer is a monolayer of group-III atoms.

32. A method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of:

a) extracting surface oxides from a surface of the substrate by thermal desorption, the thermal desorption including the steps of:

al) heating the substrate to a temperature of about 600°C; and

a2) annealing the substrate for about 10 minutes under a pressure of As_2 vapor of about 0.008 pa;

b) depositing a condensed layer of As_2 on the surface of the substrate, depositing a condensed layer including the steps of:

b1) lowering the temperature of the substrate to about 110°C while subjecting the substrate to an As_2 vapor pressure of about 0.008 pa, whereby a condensed layer of As_2 is formed on the surface of the substrate; and

b2) adjusting the thickness of the condensed layer of As_2 by raising the temperature of the substrate to about 250°C, thereby thinning the condensed layer of As_2 to several tens of Å; and

c) depositing a mono-layer of In atoms over the condensed layer of As_2 the depositing a mono-layer comprising the steps of:

cl) introducing In vapor at a temperature of about 790°C, the temperature of the substrate being maintained around 250°C and being subjected to an As_2 vapor pressure of about 0.008 pa; and

c2) raising the temperature of the substrate to about 400°C while the As_2 vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer; wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer.

33. The method of claim 32, further comprising the step d) of epitaxially growing the InAs layer, the step d) including the steps of:

dl) introducing a flux of In vapor;

d2) introducing a flux As vapor; and

d3) maintaining the temperature of the substrate between about 400°C and about 450°C; wherein the ratio of the flux of As vapor to the flux of In vapor is maintained at about 2.5.

34 (Withdrawn)

35 (Withdrawn)

36 (Withdrawn)

37 (Withdrawn)

38 (Withdrawn)

39. The method of claim 1, wherein the first crystal comprises the first material of the first layer and the second crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species.

40. The method of claim 27, wherein the first crystal comprises the first material of the first layer and the crystal comprises the second material of the second layer, and wherein the first material is a group-V species and the second material is a group-III species.